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Effect of foliar application of micronutrients on growth and yield attributes of cucumber (*Cucumis sativus* l.) under eastern Uttar Pradesh condition

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Abstract
This study investigates the effect of foliar micronutrient application on the growth and yield of cucumber (*Cucumis sativus* L.) under the agro-climatic conditions of eastern Uttar Pradesh. A field experiment was conducted during the 2023–2024 growing season at the Department of Horticulture, Udai Pratap (Autonomous) College, Varanasi, following a randomized block design (RBD) with three replications and seven treatments. The treatments included different concentrations of zinc sulphate ($ZnSO_4$), ferrous sulphate ($FeSO_4$), and boric acid, applied at 25 and 45 days after transplanting (DAT). The results demonstrated that micronutrient application significantly influenced key growth and yield parameters. Among the treatments, $ZnSO_4$ at 50 ppm (T_2) was the most effective, leading to significant improvements in fruit length, fruit diameter, number of branches per plant, number of leaves per plant, vine length, fruit weight, and total number of fruits per plant. Moreover, T_2 markedly increased total yield, enhanced fruit shelf-life, reduced days to flowering, and minimized fruit drop. These findings suggest that foliar application of $ZnSO_4$ at 50 ppm is highly beneficial for optimizing cucumber growth and yield in eastern Uttar Pradesh condition. The study recommends $ZnSO_4$ at 50 ppm for cucumber growers seeking enhanced productivity and economic benefits.

Keywords: Cucumber, fruit, ppm, growth, yields etc

Introduction

Cucumber (*Cucumis sativus* L.) is a popular warm-season vegetable from the Cucurbitaceae family, with a chromosome number of 2n=14. It is grown worldwide for its tender, edible fruits, thriving in tropical and subtropical climates (Lata *et al.*, 2018) [12]. Cucumber is widely consumed and valued for its cooling effect, as well as its ability to prevent constipation, jaundice, and indigestion. Its nutritional content includes 96.3 g of moisture, 0.4 g of protein, 0.3 g of minerals (140 mg calcium, 30 mg phosphorus, and 0.6 mg iron), 0.4 g of fiber, 5.7 g of carbohydrates, 0.04 mg of riboflavin, 0.4 mg of niacin, and 4.0 mg of vitamin C (Meena *et al.*, 2017) [14]. Micronutrients such as zinc, iron, and boron are essential for plant growth and development, even though they are required in smaller quantities compared to macronutrients (Singh *et al.*, 2020) [20]. These elements play a crucial role in photosynthesis, enzyme activity, and hormone regulation, directly influencing plant health and productivity (Sharma *et al.*, 2018) [17]. A deficiency in these nutrients can result in slow growth, poor fruit quality, and reduced yields. To address this issue, effective nutrient management strategies are essential. Foliar application of micronutrients is an effective method for overcoming soil nutrient deficiencies. This technique involves spraying nutrient solutions directly onto the leaves, enabling rapid absorption and efficient utilization by plants (Havlin *et al.*, 2014) [4]. Research has shown that foliar application enhances plant growth by improving plant height, leaf area, and flowering while also increasing fruit yield and quality in cucumbers (Kumar & Singh, 2019) [10]. As consumer demand for high-quality produce rises, optimizing foliar nutrient application is becoming increasingly important. Factors such as fruit size, weight, color, acidity, and flavor influence market acceptance and profitability for cucumber growers. Applying micronutrients at the right growth stage helps improve these qualities. However, despite the growing use of foliar feeding among cucumber farmers, there are still limited guidelines on the best nutrient combinations, concentrations, and application timing. Nutrient deficiencies can cause major crop losses, leading to problems such as poor fruit set, deformities, and nutritional disorders. These issues become more severe in later growth stages when plants struggle to absorb enough nutrients through their roots. For example, boron is essential for plant growth but moves slowly within plant tissues. Foliar application is an effective way to prevent deficiencies and improve fruit quality. Developing a well-planned foliar nutrient application schedule is crucial for increasing cucumber yield and ensuring high-quality production. This study aims to examine the effects of foliar micronutrient application on cucumber growth and yield. The findings will help improve nutrient management strategies and provide valuable insights for cucumber cultivation.

Materials and methods

The study was conducted in the experimental field of the Horticulture Department, Udai Pratap Autonomous College, Varanasi (U.P.), during the 2023–24 growing season. The objective was to evaluate the effect of foliar application of micronutrients on the growth and yield parameters of cucumber (*Cucumis sativus* L.) cv. Vinayak. The experiment was designed using a Randomized Block Design (RBD) with three replications and seven treatments, which included different concentrations of zinc sulphate (25 and 50 ppm), iron sulphate (50 and 100 ppm), and boric acid (25 and 50 ppm), along with a control. Foliar sprays were applied at 25 and 45 days after sowing (DAS). The study assessed growth and yield parameters such as days to first flowering, days to 50% flowering, number of branches per plant, number of leaves per plant, vine length, inter-nodal length, fruit length, fruit diameter, fruit drop, fruit weight, fruit volume, number of fruits per vine, yield per plant, and fruit yield per hectare. Days to first flowering and 50% flowering were recorded based on the number of days taken for the first flower bud to appear and for 50% of the plants to bear flowers in each treatment plot. The number of branches per plant was recorded by counting the primary branches of selected plants at 60 DAS. Similarly, the number of leaves per plant was determined by counting the total leaves at 60 DAS. Vine length was measured in centimetres from the base of the main vine to the tip at 60 DAS. Inter-nodal length was calculated by measuring the space between nodes in five plants from the middle of the vine using a scale, and the average was expressed in centimetres. Fruit length was recorded using a measuring scale, taking an average from five healthy fruits selected at the marketable stage. Fruit diameter was measured at three points—stalk end, middle, and floral end—using vernier calipers, and the average diameter were calculated. The percentage of fruit drop is determined by comparing the number of fruits that initially set at the pea stage to the number of fruits that reach maturity. The difference between these two counts represents the total number of dropped fruits. This difference is then expressed as a percentage of the initial fruit count to determine the overall fruit drop percentage. Five randomly selected fruits from each treatment were weighed using a physical balance, and the average fruit weight was recorded in grams. The volume of five randomly chosen fruits per treatment was determined using the water displacement method, with the average volume expressed in cubic centimetres (cc). The number of fresh marketable fruits was recorded from three randomly selected plants per treatment at each harvest, and the average number of fruits per vine was calculated. Total fruit yield per plant was obtained by summing the weight of all marketable fruits harvested from five tagged plants, with the average yield per plant expressed in kilograms. The fruit yields per hectare were estimated by multiplying the average fruit yield per vine by the total number of vines per hectare. All collected data on growth and yield parameters were statistically analyzed to determine the effects of the foliar application of micronutrient Cucumber.

Results and Discussion

The study results on the effect of foliar application of micronutrients on the growth and yield of cucumber (*Cucumis sativus* L.) cv. Vinayak under eastern Uttar Pradesh condition, along with relevant discussions, are presented. The number of days to first flowering was significantly influenced by all treatments. The shortest time to first flowering (26.33 days) was recorded with T2 ($ZnSO_4$ @50ppm), followed by T1 ($ZnSO_4$ @25ppm) and T6 (Boric acid @50ppm). In contrast, the longest time to first flowering (34.67 days) was observed in the control. Similarly, the shortest time to reach 50% flowering (35.00 days) was recorded with T2 ($ZnSO_4$ @50ppm), followed by T1 ($ZnSO_4$ @25ppm) and T6 (Boric acid @50ppm), while the longest time (46.33 days) was noted in the control (T7). All the micronutrient treatments effectively reduced the time to first flowering and 50% flowering compared to the control. The foliar application of zinc and boron has been shown to accelerate flowering in cucumber plants, which is beneficial for extending the harvesting period and increasing yield potential. Studies by Sidhu *et al.* (2020) [18] reported that foliar application of zinc on cucumber reduced the time to flowering. Similarly, Kumar *et al.,* (2023) [9] found that boron application led to earlier flowering, shortening the flowering period. This early flowering effect is attributed to the role of these micronutrients in promoting the synthesis of growth hormones that trigger flowering. These findings align with the results of Zhao *et al.,* (2013) [23] and Tzerakis *et al.,* (2013) [21]. The numbers of branches per plant were influenced by different treatments. The highest number of branches per plant (9.67) was recorded with T2 ($ZnSO_4$ @50ppm), followed by T1 ($ZnSO_4$ @25ppm) and T6 (Boric acid @50ppm). In contrast, the lowest number of branches per plant (5.33) was observed in the control. The application of micronutrients has been shown to increase branching, which directly impacts the plant's ability to produce more fruits. Sidhu *et al.,* (2020) [18] reported that foliar application of zinc and boron led to a increase in the number of branches. Increased branching provides a stronger framework for fruit development, allowing better nutrient distribution and improving overall productivity. The present finding is agreed with the finding of Kazemi, M. (2013) [5], Moghaddasi *et al,* (2017) [15] and Küçükyumuk *et al.,* (2014) [8]. The highest number of leaves per plant (74.33) was recorded with T2 ($ZnSO_4$ @50ppm), followed by T1 ($ZnSO_4$ @25ppm) and T6 (Boric acid @50ppm). In contrast, the lowest number of leaves per plant (47.33) was observed in the control. The number of leaves per plant is an important factor as it reflects the plant's photosynthetic capacity and overall growth. Kazemi, M., (2013) [5] conducted an experiment demonstrating that foliar applications of zinc and iron, both individually and in combination, significantly increased the number of leaves per plant. More leaves enhance the plant's photosynthetic area, leading to better growth and higher yield potential. The results of this study confirm that applying zinc (Zn) promotes vegetative growth in cucumber plants. These findings are consistent with the studies of Küçükyumuk *et al.,* (2014) [8], Deshmukh (2014) [2], and Zhao *et al.,* (2013) [23]. The longest vine length (198.33 cm) was recorded with the application of T2 ($ZnSO_4$ @50ppm), followed by T1 ($ZnSO_4$ @25ppm) and T6 (Boric acid @50ppm). In contrast, the shortest vine length (155.33 cm) was observed in the control. Similarly, the maximum internodal length (11.17 cm) was recorded with T2 ($ZnSO_4$ @50ppm), followed by T1 ($ZnSO_4$ @25ppm) and T6 (Boric acid @50 ppm), while the shortest internodal length (7.13 cm) was noted in the control. Vine length and internodal length play a crucial role in the vegetative growth of cucumber plants. The application of zinc has been found to promote vine length while optimizing internodal length. Kazemi, M., (2013) [5] reported that the application of zinc significantly increased vegetative growth parameters, including vine length, in cucumber plants. These findings align with the research of *Moghaddasi et al.,* (2017) [15], Küçükyumuk *et al.,* (2014) [8], and Tzerakis *et al.,* (2012). The longest fruit (14.47 cm) was recorded with the application of T2 ($ZnSO_4$ @50ppm), followed by T1 ($ZnSO_4$ @25ppm) and T6 (Boric acid @50 ppm). In contrast, the shortest fruit (10.07 cm) was observed in the control. Similarly, the largest fruit diameter (4.23 cm) was recorded with T2 ($ZnSO_4$ @50ppm), followed by T1 ($ZnSO_4$ @25ppm) and T6 (Boric acid @50 ppm), while the smallest fruit diameter (2.73 cm) was noted in the control. Fruit size is an important quality factor in cucumbers, and foliar application of micronutrients like zinc and boron has been found to significantly improve fruit length and diameter. Raturi, *et al.,* (2020) [16] reported that application of micronutrients significantly increased fruit length and diameter, leading to improved overall yield and economic returns. These improvements in fruit size are attributed to better nutrient absorption and enhanced movement of nutrients to developing fruits. All micronutrient treatments improved cucumber size compared to the control. These results align with the findings of Dominy (2010) [3] and Marschner *et al.,* (1990) [13]. The data on average fruit drop percentage showed that all treatments significantly reduced fruit drop. The lowest fruit drop (12.33%) was recorded with the application of T2 ($ZnSO_4$ @50ppm), followed by T1 ($ZnSO_4$ @25ppm) and T6 (Boric acid @50ppm). In contrast, the highest fruit drop (24.67%) was observed in T7 (control). Fruit drop is a common problem in cucumber cultivation that can lead to significant yield losses. The application of micronutrients like boron and zinc has been found to reduce fruit drop by improving fruit set and strengthening the attachment between the fruit and the plant. Uikey *et al.,* (2018) [22] studied the impact of foliar application of zinc and boron on tomato plants and found that it significantly reduced fruit drop. Their research highlighted that these micronutrients play a crucial role in improving fruit retention by enhancing nutrient uptake, maintaining hormonal balance, and reducing physiological disorders that lead to premature fruit shedding. The data clearly shows that the highest fruit weight (126.73 g) was recorded with the application of T2 ($ZnSO_4$ @50ppm), followed by T1 ($ZnSO_4$ @25ppm) and T6 (Boric acid @50 ppm). In contrast, the lowest fruit weight (94.50 g) was observed in T7 (control). The application of micronutrients, especially zinc and boron, has been proven to significantly increase the average fruit weight in cucumbers. Khan *et al.,* (2013) [6] found that the combined application of zinc and iron resulted in a significant increase in average fruit weight of cucumber plants. This improvement is due to better nutrient absorption and efficient distribution of nutrients to the developing fruits. In this study, the highest fruit weight was recorded with T2 ($ZnSO_4$ @50ppm), while the lowest was observed in T7 (control). These findings align with previous studies by Moghaddasi *et al.,* (2017) [15], Deshmukh (2014) [2], and Zhao *et al.,* (2013) [23]. The data shows that the highest fruit volume (117.33 cc) was recorded with the foliar application of T2 ($ZnSO_4$ @50 ppm), followed by T1 ($ZnSO_4$ @25 ppm) and T6 (Boric acid @50 ppm). In contrast, the lowest fruit volume (105.00 cc) was observed in the control (water spray). Fruit volume is an important factor affecting cucumber yield, and it is significantly influenced by micronutrient application. Singh *et al.,* (2015) [19] found that foliar application of zinc and boron (1% each) significantly increased fruit volume in guava. This increase is due to improved cell division and expansion during fruit development, supported by essential nutrients. Similarly, Kumar *et al.,* (2020) [11] demonstrated that the foliar application of zinc combined with boron significantly increased fruit volume in cucumber plants. The observations on the average number of fruits per vine show that all treatments performed significantly better than the control. The highest number of fruits per vine (23.67) was recorded with the foliar spray of T2 ($ZnSO_4$ @50 ppm), followed by T1 ($ZnSO_4$ @25 ppm) and T6 (Boric acid @50 ppm). In contrast, the lowest number of fruits per vine (13.33) was observed in the control (water spray). The number of fruits per plant is directly related to overall yield and is greatly influenced by micronutrient application. This improvement was due to better flower retention and fruit set, likely supported by improved hormonal balance from the applied micronutrients. Kumar *et al.,* (2019) [10] found that zinc application enhanced pollination efficiency, leading to an increased number of fruits per plant. These results are consistent with the findings of Zhao *et al.,* (2013). The highest yield per plant (2.88 kg) was recorded with T2 ($ZnSO_4$ @50ppm), followed by T1 ($ZnSO_4$ @25ppm) and T6 (Boric acid @50ppm). In contrast, the lowest yield per plant (1.23 kg) was observed in the control. Fruit yield per plant is a key factor in determining overall cucumber productivity. Research has shown that foliar application of micronutrients can greatly enhance this yield. All treatments significantly increased fruit yield compared to the control. Research has shown that applying micronutrients significantly increases yield. These findings align with the results of Kietsermkajorn *et al.,* (2010) [7]. The data clearly show that the highest fruit yield (12.80 t/ha) was recorded with the application of T2 ($ZnSO_4$ @50ppm), followed by T1 ($ZnSO_4$ @25ppm) and T6 (Boric acid @50ppm). In contrast, the lowest fruit yield (7.09 t/ha) was observed in the control treatment. These findings align with previous research by Moghaddasi *et al.,* (2017) [15], Zhao *et al.,* (2013), and Aydin *et al.,* (2012) [1]. Sidhu *et al.* (2020) [18] reported a comparable rise in yield after applying zinc and boron, highlighting the crucial role of these micronutrients in improving plant productivity. At the field level, fruit yield per hectare is the ultimate measure of a crop's productivity.

Table 1: Effect of Foliar Application of Micronutrients on Growth and Yield Attributes of Cucumber (*Cucumis sativus* L.) under eastern Uttar Pradesh condition

S.No.	Treatments	Days to first flowering	Days to 50 % flowering	Number of leaves per plant	Number of branches per plant	Vine length (cm)	Inter-nodal length (cm)	Fruit drop (%)	Length of fruit (cm)	Diameter of the fruit (cm)	Fruit weight (g)	Volume of fruit (ml)	Number of fruits per plant	Fruit yield per plant (kg)	Fruit yield (t/ha)
1	T1	27.00	36.67	68.33	8.67	186.33	10.13	14.50	14.04	3.97	123.17	113.17	21.67	2.72	11.74
2	T2	26.33	35.00	74.33	9.67	198.33	11.17	12.33	14.47	4.23	126.73	117.33	23.67	2.88	12.80
3	T3	31.00	42.67	55.67	6.67	168.67	8.13	21.83	10.73	3.17	109.33	107.50	16.33	2.07	8.52
4	T4	30.33	41.00	59.67	7.33	173.67	8.67	19.83	11.53	3.53	113.50	108.50	18.67	2.23	9.81
5	T5	29.00	39.67	61.67	7.67	179.33	9.03	18.17	12.17	3.77	116.83	110.33	20.67	2.37	10.04
6	T6	28.67	37.33	64.33	8.33	185.67	9.33	15.67	13.73	3.83	119.77	111.50	21.33	2.53	11.29
7	T7	34.67	46.33	47.33	5.33	155.33	7.13	24.67	10.07	2.73	94.50	105.00	13.33	1.23	7.09
	CV (%)	6.44	3.60	6.53	13.04	4.5	7.77	10.74	6.4	7.1	4.8	1.7	9.1	10.7	11.0
	SEm±	1.10	0.83	2.32	0.58	4.63	0.41	1.13	0.46	0.15	3.18	1.10	1.02	0.14	0.63
	CD (P=0.05)	3.39	2.55	7.16	1.78	14.26	1.26	3.47	1.41	0.46	9.81	3.38	3.13	0.44	1.96

Conclusion

The study concludes that foliar application of micronutrients, including zinc sulphate, boric acid, and iron sulphate, significantly improved the growth and yield of cucumber. Among the treatments, T_2 ($ZnSO_4$ @50 ppm) proved to be the most effective in enhancing various growth parameters such as the number of branches and leaves per plant, vine length, and internodal length. Plants treated with this concentration exhibited better vegetative growth compared to the control. In terms of flowering, the use of micronutrients, particularly T_2 ($ZnSO_4$ @50 ppm), led to a significant reduction in the number of days required for first flowering and 50% flowering, indicating early reproductive growth. The highest fruit weight and volume were observed with T_2 application, highlighting its role in improving fruit size and overall quality. Another significant outcome was the reduction in fruit drop, with T_2 ($ZnSO_4$ @50 ppm) showing the lowest percentage of fruit drop. This treatment also resulted in the highest number of fruits per vine, which directly contributed to a substantial increase in overall yield. The maximum fruit yield per plant and per hectare was recorded with T_2 application, while the lowest was observed in the control treatment. Based on these findings, the foliar application of $ZnSO_4$ @50 ppm (T_2) is highly recommended for cucumber cultivation in eastern Uttar Pradesh. It not only enhances growth and yield but also improves fruit quality and shelf life while reducing fruit drop.

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