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Impact of foliar micronutrient application on yield and economic returns of okra [*Abelmoschus esculentus* (L.) Moench]

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Abstract
This research study was conducted at the Regional Horticultural Research Station, Navsari Agricultural University, Navsari, and Gujarat during summer, 2024. The research experiment was laid out in a Randomized Block Design (RBD) with nine treatments, each replicated thrice, to assess the impact of foliar micronutrient application on yield and economic returns of okra [*Abelmoschus esculentus* (L.) Moench]. The treatments included T_1 - Ammonium molybdate @ 0.1 % , T_2 - Boric acid @ 0.2 %, T_3 - Zinc sulphate @ 0.5 %, T_4 - Copper sulphate @ 0.5 %, T_5 - Ferrous sulphate @ 0.5 %, T_6 - Manganese sulphate @ 0.5 %, T_7 - General grade – IV (Fe-2.0, Mn-0.5, Zn-4.0, Cu-0.3 and B-0.5) @ 1.5 %, T_8 - General grade - IV @ 1.5 % + T_3 and T_9 - Control (No spray). Among all treatments, T_8 significantly improved pod length (10.97 cm), pod girth (5.77 cm), number of pods per plant (19.67), pod weight per plant (195.20 g), pod yield per net plot (7.03 kg) and pod yield per hectare (14.47 t). It also resulted highest net income (₹3,11,391/ha) and benefit-cost ratio (2.48) when applied as foliar sprays at 25 DAS and 40 DAS compared to control.

Keywords: Okra, foliar application, micronutrients, yield, economics

Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is an important vegetable crop widely cultivated in tropical and subtropical regions for its nutritional and culinary value. The species is an allotetraploid (2n = 130-140) and requires a long, warm growing season, being sensitive to frost. Optimal growth occurs at daytime temperatures of 25-40°C and night temperatures above 22°C. Well-drained medium black or light clay soils rich in organic matter, with a pH of 6.0–6.8 are most suitable for its cultivation (Pateliya *et al.*, 2014) [11].

Okra pods are nutritionally rich, containing per 100 g: water 88.6 g, protein 2.1 g, carbohydrate 8.2 g, fat 0.2 g, fiber 1.7 g, calcium 84 mg, phosphorus 90 mg, iron 1.2 mg, β-carotene 185 µg, riboflavin 0.08 mg, thiamine 0.04 mg, niacin 0.6 mg and ascorbic acid 47 mg. The plant also exhibits diuretic properties and has been used in medical applications as a plasma substitute or blood volume extender (Kumar *et al.*, 2010) [8].

Micronutrients are essential for plant growth and productivity, participating in key physiological and biochemical processes including enzyme activation and metabolic regulation. Deficiency or imbalance can reduce yield and affect crop quality (Tariq Aftab, 2020) [15]. Proper management of micronutrients not only enhances yield but also improves the nutritional quality of okra, contributing to better human health.

Materials and Methods

A field experiment entitled was conducted during the summer season of 2024 at the Vegetable Research Farm, Regional Horticultural Research Station, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, and Gujarat. It is located at 20°37′ N latitude, 72°54′ E longitude and 11.83 m above mean sea level and falls under the South Gujarat Heavy Rainfall Zone (AES-III). The experiment was laid out in a Randomized Block Design (RBD) comprising nine treatments and three replications. The treatments were: T_1 – Ammonium molybdate @ 0.1%, T_2 – Boric acid @ 0.2%, T_3 – Zinc sulphate @ 0.5%, T_4 – Copper sulphate @ 0.5%, T_5 – Ferrous sulphate @ 0.5%, T_6 – Manganese sulphate @ 0.5%, T_7 – General Grade-IV (Fe 2.0%, Mn 0.5%, Zn 4.0%, Cu 0.3%, B 0.5%) @ 1.5%, T_8 – General Grade-IV @ 1.5% + Zinc sulphate @ 0.5%, and T_9 – Control (no foliar spray). Foliar applications were applied twice at 25 DAS and 40 DAS. The crop variety used was GNO-1 (Purna Rakshak). The experimental field was prepared by ploughing, harrowing and levelling before sowing. Seeds were sown manually with spacing of 45 cm × 30 cm, gross plot size of 3.6 m × 2.4 m and net plot size of 2.7 m × 1.8 m. A seed rate of 12 kg ha^{-1} was used. The recommended dose of fertilizers (100:50:50 N:P:K kg ha^{-1}) was applied along with 10 t ha^{-1} of well-decomposed farmyard manure.

Yield observations were recorded from the net plot area by harvesting all marketable pods from five randomly tagged plants at each picking. Economic analysis was performed using the average market price of okra (30 ₹/kg) and the total cost of cultivation for each treatment. The total cost of cultivation was computed by adding the variable cost components and the fixed cost components. Gross income (₹ ha^{-1}) was calculated from the mean pod yield and market price, while net income (₹ ha^{-1}) was derived by subtracting the total cost of cultivation from the gross income. The benefit–cost ratio (B:C) was computed as the ratio of net return to the cost of cultivation. All recorded data were statistically analyzed using the Analysis of Variance (ANOVA) technique appropriate to the Randomized Block Design (Panse and Sukhatme, 1985) [10].

Result and Discussion

The study revealed that foliar application of micronutrients, either individually or in combination, significantly influenced the yield attributes and economic returns of okra compared to the control, as presented in Table 1 and table 2. Among all treatments, the combined foliar application of General grade-IV @ 1.5% + Zinc sulphate @ 0.5% (T_8) was most effective, recording the maximum pod length (10.97 cm), pod girth (5.77 cm), number of pods per plant (19.67), pod weight (195.20 g/plant) and pod yield (14.47 t/ha) followed by T_7. General grade-IV @ 1.5% + Zinc sulphate @ 0.5% (T_8) also recorded higher net income (₹3,11,391/ha) and benefit-cost ratio (2.48) followed by T_3.

Table 1: Impact of foliar micronutrient application on yield attributes of okra

Treatment	Pod length (cm)	Pod girth (cm)	Number of pods/plant	Weight of pod/plant (g)	Pod yield (kg/net plot)	Pod yield (t/ha)
T_1	9.55	4.24	14.73	143.86	5.19	10.67
T_2	10.66	4.78	14.33	140.86	5.08	10.46
T_3	9.24	5.56	16.33	168.75	6.09	12.52
T_4	8.90	4.75	14.47	142.63	5.14	10.58
T_5	9.35	4.93	13.80	135.80	4.89	10.07
T_6	9.10	4.87	15.20	146.77	5.29	10.89
T_7	10.79	5.59	17.60	172.37	6.21	12.78
T_8	10.97	5.77	19.67	195.20	7.03	14.47
T_9	9.23	4.11	12.73	124.75	4.50	9.26
SEm (±)	0.41	0.22	0.51	6.29	0.23	0.47
CD at 5 %	1.23	0.66	1.48	18.86	0.68	1.40
CV (%)	7.27	7.71	10.21	7.15	7.14	7.14

Table 2: Economics of different foliar micronutrient treatments in okra (₹/ha)

Treatments	Pod yield (kg/ha)	Fixed cost (₹/ha)	Variable cost (₹/ha)	Total cost of cultivation (₹/ha)	Gross income (₹/ha)	Net income (₹/ha)	B:C ratio
T_1	10,670	1,17,292	6,904	1,24,196	3,20,100	1,98,391	1.58
T_2	10,460	1,17,292	2,704	1,19,996	3,13,800	1,96,291	1.63
T_3	12,520	1,17,292	3,404	1,20,696	3,75,600	2,57,391	2.13
T_4	10,580	1,17,292	3,904	1,21,196	3,17,400	1,98,691	1.63
T_5	10,070	1,17,292	3,154	1,20,446	3,02,100	1,84,141	1.52
T_6	10,890	1,17,292	3,654	1,20,946	3,26,700	2,08,241	1.72
T_7	12,780	1,17,292	6,404	1,23,696	3,83,400	2,62,191	2.11
T_8	14,470	1,17,292	7,904	1,25,196	4,34,100	3,11,391	2.48
T_9	9,260	1,17,292	00	1,17,292	2,77,800	1,62,995	1.38

The improvement in yield and economic performance under T_8 can be attributed to the synergistic action of multiple micronutrients enhancing physiological efficiency and metabolic coordination. Zinc promotes auxin synthesis, protein metabolism and membrane stability, thereby improving vegetative growth and reproductive development (Balafrej *et al*., 2020) [3]. Iron facilitates chlorophyll biosynthesis and electron transport, sustaining higher photosynthetic activity and assimilate production (Li *et al*., 2021). Boron ensures proper cell wall formation and pollen tube growth, which support effective fertilization and fruit set (Shireen *et al*., 2018) [14]. Molybdenum contributes to nitrogen metabolism and stress regulation through its involvement in nitrate reductase and abscisic acid synthesis (Bajguz and Piotrowska-Niczyporuk, 2023; Weber *et al*., 2023) [2]. Manganese and copper enhance antioxidant enzyme activity, protecting chloroplast membranes and ensuring efficient photosynthetic functioning (Ghorbani *et al*., 2019) [6]. The cumulative effect of these micronutrients improved source-sink balance, better assimilate translocation and enhanced pod development leading to higher yield and profitability. These findings are consistent with earlier reports by Dubalgunde *et al*. (2017) [5], Arya *et al*. (2021), Das *et al.* (2021), Singh *et al.* (2025), Singh *et al.* (2022), Javeed *et al*. (2023) and Adhikari *et al*. (2024) [1, 7, 12, 13]. Hence, the combined foliar application of General grade-IV @ 1.5% + Zinc sulphate @ 0.5% (T_8) can be recommended for achieving higher productivity and better economic returns in okra cultivation under similar agro-climatic conditions. Economic returns varied among treatments due to differences in pod yield and variable input costs. Since fixed costs were identical for all treatments, variation in total cost of cultivation was mainly attributed to expenditure incurred on micronutrient application. Micronutrient-treated plots recorded higher gross returns over the control owing to increased pod yield, which compensated for the additional variable cost. Among the treatments, T_8 (General Grade-IV @ 1.5% + zinc sulphate @ 0.5%) recorded the highest gross income, net income and benefit–cost ratio, followed by T_7 and T_3. Although T_8 involved higher variable cost, the increased yield resulted in superior economic returns. The control treatment recorded the lowest net income and benefit-cost ratio due to lower pod yield.

Conclusion

The results of the study revealed that among all foliar applications of micronutrients tested at 25 and 40 DAS, the treatment T_8 (General Grade-IV @ 1.5% + Zinc sulphate @ 0.5%) was found to be the most effective. This treatment significantly improved yield attributes such as pod length, pod girth, number of pods per plant, weight of pods and overall pod yield. The highest net return and benefit-cost ratio were also obtained with T_8. Hence, T_8 (General Grade-IV @ 1.5% + Zinc sulphate @ 0.5%) is identified as the most efficient and profitable treatment for okra cultivation under the given conditions.

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