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Effects of Micronutrient Supplements on Rooftop Ginger Cultivation

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ABSTRACT

The growing global population and urbanization are placing much demand for innovative food production methods, especially in cities with less arable land. Rooftop agriculture presents a promising solution, but limited soil volume and nutrient deficiency can restrict productivity. This study examines the use of micronutrient supplements to improve the growth and yields of ginger (*Zingiber officinale* Rosc.) on rooftop. The experiment was laid out in a completely randomized design where treated (T-1) and control (T-0) were used, with foliar micronutrient sprays applied at 10-day intervals. The study evaluated the growth and yield parameters of ginger, such as tiller number, plant height, fresh leaf weight, dry leaf weight, and rhizome yield, while profitability was also analyzed. The T-1 group was found to be statistically better than T-0, and maximum values were recorded for plant height at 49.93 cm, leaf length at 21.12 cm, and rhizome yield at 240.79 g. Moreover, leaf width (2.59 cm), fresh leaf weight (0.58 g), and dry leaf weight (0.11 g) were increased compared to T-0. Also, with a Benefit-Cost Ratio of 1.34, T-1 proved to be more economical than T-0 (1.04). These findings provide valuable insights about this simple and cheap remedy for micronutrient deficiencies, which can enhance ginger productivity in rooftop farming.

Keywords: BCR, Deficiency, Foliar spray, Ginger, Micronutrient, Rooftop agriculture

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1. INTRODUCTION

Ginger, scientifically classified as *Zingiber officinale* Rosc. is a significant spice crop belonging to the Zingiberaceae family. It is a widely cultivated tropical herbaceous perennial esteemed for its culinary adaptability and various medicinal properties (Siddiqui et al., 2023). It is commonly used to manage gastrointestinal disorders, such as dyspepsia, nausea, and diarrhea (Supriya et al., 2020). As a significant agricultural commodity, ginger plays a vital role in the economies of many developing countries, where it is a source of income for millions of smallholder farmers. In Bangladesh during 2022-2023, ginger cultivation spanned 25,687.70 acres, yielding a total production of 83,726.18 metric tons (BBS, 2023). Ginger cultivation thrives under specific agro-climatic conditions, primarily warm and humid environments, with well-drained, fertile soils rich in organic matter (Kumar et al., 2025).

Micronutrients are essential elements needed in minimal quantities yet crucial for plant growth and development, affecting numerous physiological processes such as photosynthesis, energy production, and pathogen resistance (Sial et al., 2022). In traditional farming environments, maintaining the appropriate levels of micronutrients in the soil

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is essential for enhancing plant health and productivity. In urban agriculture, particularly in unconventional growing settings such as rooftops, the nutrient content of natural soil may be restricted, making it a considerable challenge to sustain an optimal nutrient balance (Chakraborty et al., 2021). It is essential to address micronutrient deficiencies to improve both crop yield and quality in these challenging environments.

Foliar spray containing micronutrients can be a novel approach to supplementing essential nutrients in an urban agricultural setting. This study explores the potential benefits of this innovative supplementation method on the growth and yield of ginger plants cultivated in rooftop bags. Specifically, it investigates whether micronutrients can effectively be repurposed to enhance ginger's vegetative and reproductive growth. Prior research has demonstrated the significance of micronutrients in improving plant growth and increasing the yield of different crops in field conditions (Alkarawi & Hasan, 2021; Sarker et al., 2018; Singh et al., 2018). However, the application of such nutrients in the case of ginger cultivation on rooftops remains underexplored in an urban agricultural context. This research aims to fill this gap by evaluating the effects of micronutrient supplements on key growth parameters such as tiller number, plant height, leaf length, leaf width, and crucial yield metrics, including fresh and dry leaf weights and rhizome yield in ginger. The outcomes of this study could provide valuable insights into the viability of using micronutrient supplements as a sustainable strategy to improve urban agricultural practices and enhance food security in urban settings.

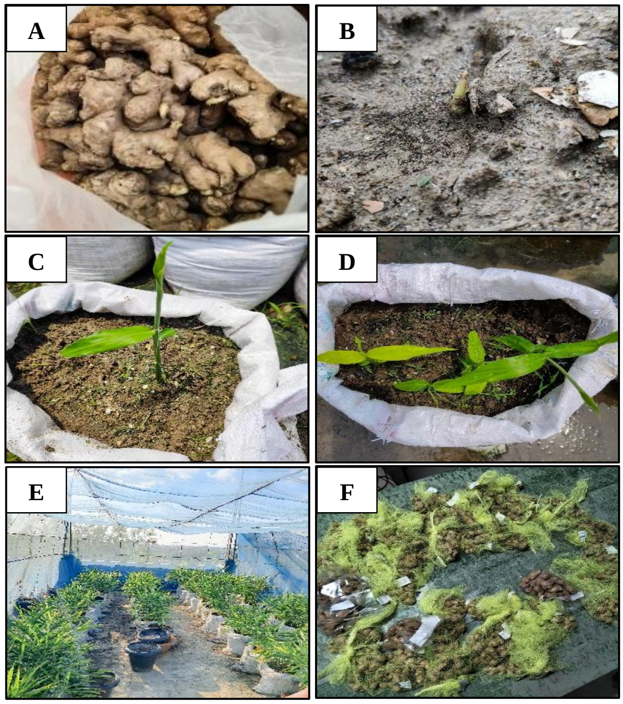

Fig. 1 Different growing stages of ginger in rooftop. A) Rhizome seeds, B) Emergence of the first sprout after 20 days of transplantation, C) Early-stage ginger seedling after 20 days of emerging, D) Tillering phase after 90 days of transplantation, E) Mature vegetative stage after 120 days of transplantation, F) Harvested ginger rhizome after 180 days of transplantation.

2. MATERIALS AND METHODS

The experiment was conducted on the rooftop of EXIM Bank Agricultural University Bangladesh, situated at 24°59'N latitude and 88°27'E longitude, at an elevation of 24.4 meters. Rhizome seeds were collected from the Department of Agricultural Extension office in Bagha, Rajshahi. The rhizomes were treated with Ridomil Gold by dipping them in a 5 g/L water solution for 15 minutes, followed by thorough washing and sun drying for 15 minutes. The treated rhizomes were then set aside to sprout for 10 days. The sprouted rhizomes were then transferred to well-prepared soil mixed in a 3:1:1 ratio of soil, sand, compost, and chemical fertilizer (urea, mop, and tsp) in a recommended dose. The recommended dose of fertilizer was applied throughout the cultivation, and pesticide (Imitaf 20 SL) was also applied at the recommended dose.

For this study, thirty bags were divided into two groups, where fifteen were treated (T-1) with a foliar spray containing micronutrients, while the remaining fifteen served as the control group (T-0) and received no treatment. Each spray contained Vitamin A (15 mg/L), Vitamin B1 (15 mg/L), Vitamin B6 (20 mg/L), Calcium Phosphate (109.2 mg/L), Vitamin C (600 mg/L), Ferrous Sulphate (500 mg/L), Manganese Sulphate (10 mg/L), Potassium Iodite (1.96 mg/L), Vitamin D (0.1mg/L), Vitamin B2 (17 mg/L), Nicotinamide (200 mg/L), Folic Acid (4 mg/L), Copper Sulphate (20 mg/L), Zinc Sulphate (370.3 mg/L), and Potassium Sulphate (111.41 mg/L). A total of 3 sprays were applied at 10-day intervals during the vegetative state (120 days after transplanting) of plant growth. For this study, a completely randomized design (CRD) was selected, and each bag was considered a replication, as it is used in many rooftop experiments and for a limited number of treatments (Sinba, 2010).

Two sprouted rhizomes were sown in each of the bags. Intercultural operations were performed at regular intervals to promote optimal growth and development. Harvesting was done when all plant leaves had turned yellow, and later, rhizomes were dried in direct sunlight for three hours. Data collection covered the period from the emergence of the tiller from the rhizome to the point of harvesting. Parameters measured included the number of tillers per bag, plant height, leaf length, leaf width, fresh and dry leaf weight, biological yield, and actual yield. Statistical analysis was performed using SPSS version 26, incorporating ANOVA and correlation analysis, where no post-hoc tests were performed as there were fewer than three groups in treatments. Some visualizations were generated in the software Python using Pandas, Seaborn, and Matplotlib libraries. Profitability analysis was calculated considering only variable production costs. Net returns were determined by subtracting the total variable cultivation costs from the gross returns. The benefit-cost ratio (BCR) was evaluated using the following formula by Acharya et al. (2019).

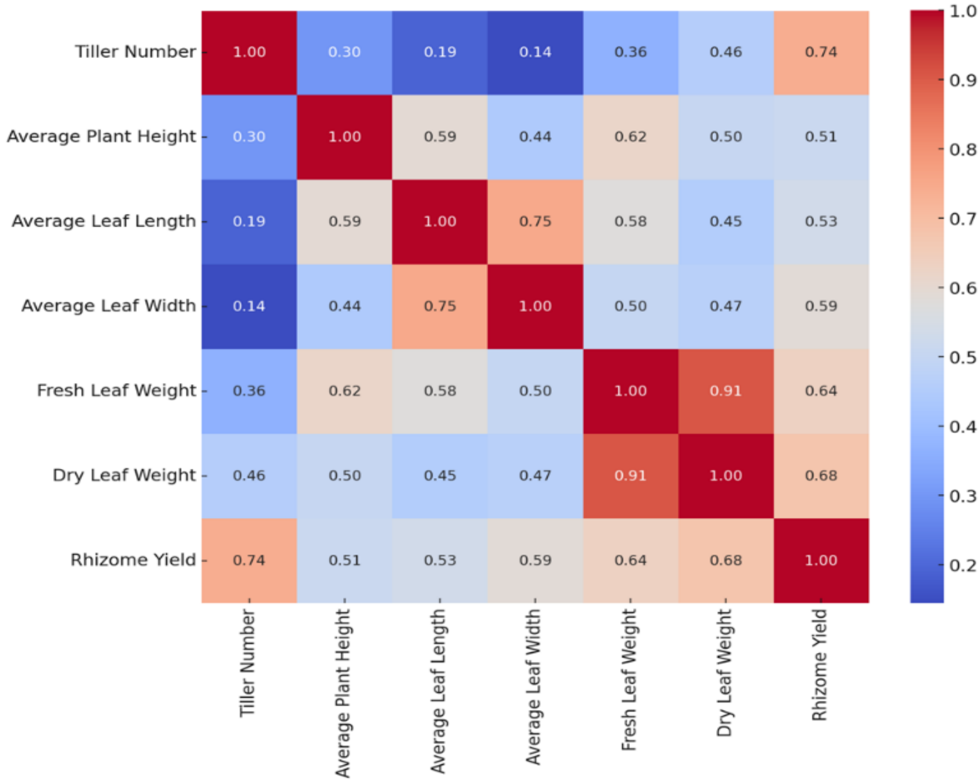

Fig. 2 Heatmap of correlation coefficients between plant growth and yield parameters. The heatmap uses a color gradient from blue to red, indicating increasing strength of positive correlation. Each cell provides a correlation co-efficient (very weak 0.00-0.20; weak 0.21-0.40; Moderate 0.41-0.60; Strong 0.61-0.80; very strong 0.91-1.00), quantifying the degree of association between pairs of variables.

$$BCR = \frac{\text{Gross Return}}{\text{Total Variable Cost}}$$

3. RESULTS

3.1 Growth and Yield Parameters

The growth and yield parameters of ginger, precisely average plant height, average leaf length, and rhizome yield, were significantly influenced by the application of micronutrient supplements (Table 1, Table 2).

Treatments	Tiller number/bag $\bar{x}$±SD	Plant height (cm)/bag $\bar{x}$±SD	Leaf length (cm)/tiller $\bar{x}$±SD	Leaf width (cm)/tiller $\bar{x}$±SD
Control (T-0)	18.53 ± 7.07a	41.11 ± 6.89b	18.09 ± 1.35b	2.35 ± 0.10b
Treated (T-1)	20.13 ± 6.46a	49.93 ± 7.98a	21.12 ± 2.31a	2.59 ± 0.17a

Table 1 Growth components of ginger (Number of sample = 30 bags)

$\bar{x}$: Mean value; SD: Standard deviation; in a column, means followed by a similar letter(s) were not significantly different whereas, means followed by dissimilar letter(s) were significantly different ($p < 0.05$).

Treatments	Fresh leaf weight (g)/tiller $\bar{x}$±SD	Dry leaf weight (g)/tiller $\bar{x}$±SD	Rhizome yield (g)/bag $\bar{x}$±SD
Control (T-0)	0.50±0.10a	0.09±0.02a	176.75±79.96b
Treated (T-1)	0.58±0.17a	0.11±0.03a	240.79±55.58a

Table 2 Yield components of ginger (Number of sample = 30 bags)

$\bar{x}$: Mean value; SD: Standard deviation; in a column, means followed by a similar letter(s) were not significantly different whereas, means followed by dissimilar letter(s) were significantly different ($p < 0.05$).

However, the number of tillers, average leaf width, fresh leaf weight, and dry leaf weight exhibited statistically insignificant yet positive effects from micronutrient treatment (Table 1, Table 2). The treated group, which received micronutrient supplements, produced the highest results for plant height (49.93 cm/bag), leaf length (21.12 cm/tiller), and

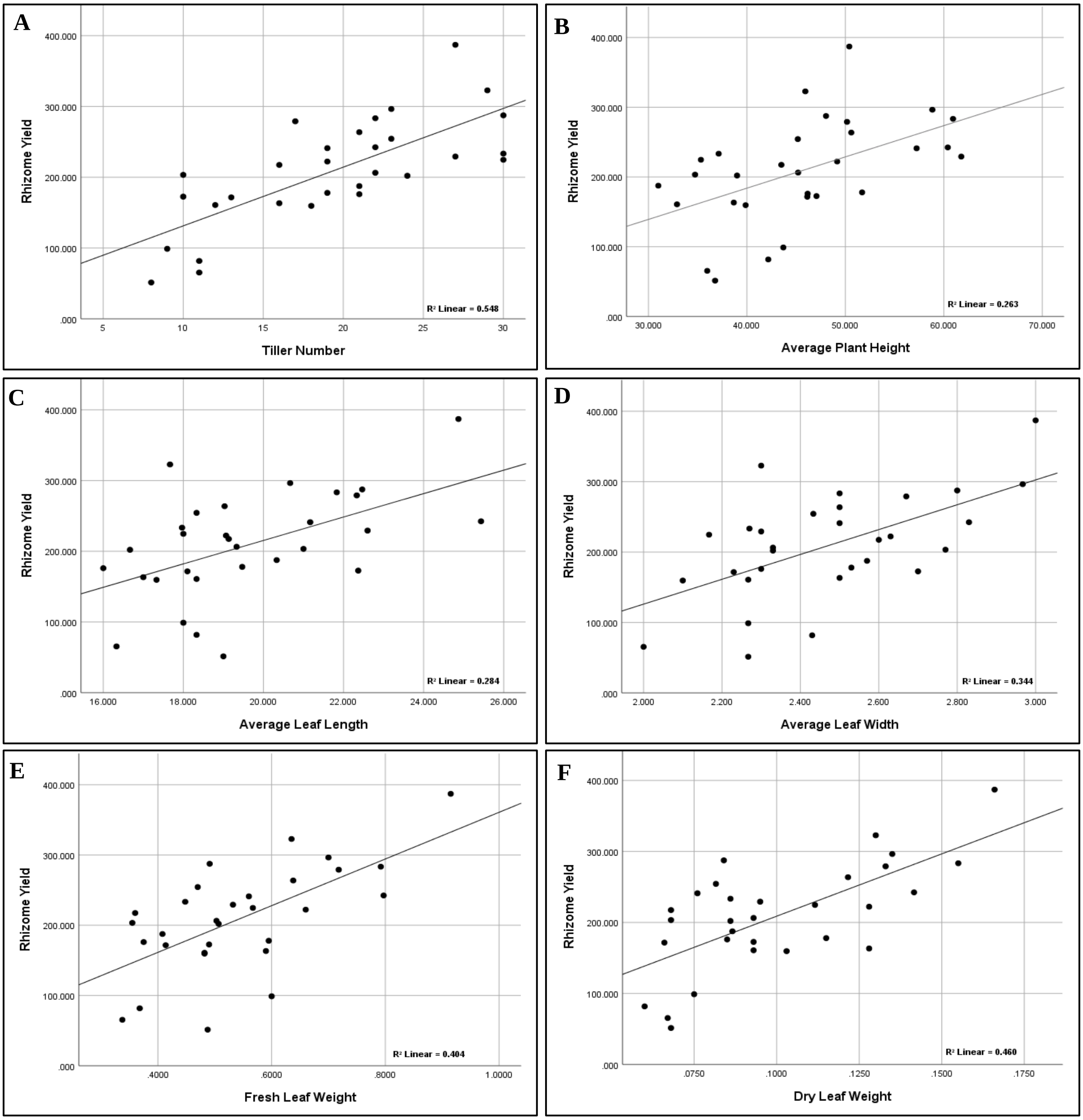

Fig. 3 Scattered diagrams of five parameters with yield. Relationship of yield with A) Tiller number, B) Plant height, C) Leaf length, D) Leaf width, E) Fresh leaf weight, F) Dry leaf weight.

rhizome yield (240.79 g/bag) while maintaining improved leaf width (2.59 cm/tiller), fresh leaf weight (0.58 g/tiller), and dry leaf weight (0.11 g/tiller). With no micronutrients supplement applied in the control group, the lowest values were obtained for average plant height (41.11 cm/Bag), average leaf length (18.09 cm/tiller), average leaf width (2.35 cm/tiller), fresh leaf weight (0.50 kg/tiller), dry leaf weight (0.09 g/tiller), and rhizome yield (176.75 g/bag). Overall, the parameters of growth and yield in the case of ginger were significantly higher in the treated group compared to the control group, suggesting the efficacy of micronutrient supplements to enhance both vegetative and reproductive aspects of ginger growth in rooftop bag environments (Table 1, Table 2, and Fig. 1).

3.2 Correlations of Parameters

The degrees of relationship among tiller number, average plant height, average leaf length, average leaf width, fresh leaf weight, dry leaf weight, and rhizome yield were analyzed. The relationship between tiller number and rhizome yield is depicted in Fig. 2. The coefficient of correlation was 0.74 at a significance level of 5%. The results demonstrated a considerably strong positive association between tiller number and rhizome yield. The scattered dots around the fit line also exhibited a significant relationship in the graph. The independent variable, tiller number, can account for 54.8% of the variability in the dependent variable, rhizome yield (Fig. 3A).

The relationship between average plant height and rhizome yield is depicted in Fig. 2. The coefficient of correlation was 0.51 at a significance level of 5%. The results demonstrated a moderate positive association between plant height and rhizome yield. The scattered dots from the fit line also suggested a significant association. The independent variable, average plant height, can account for 26.3% of the variability in rhizome yield (Fig. 3B). The relationship between average leaf length and rhizome yield is shown in Fig. 2. The coefficient of correlation was 0.53 at a significance level of 5%. The results indicated a moderate positive relationship between average leaf length and rhizome yield. The scattered dots around the fit line reflected this significant association. The independent variable, average leaf length, can explain 28.4% of the variability in rhizome yield (Fig. 3C). The relationship between average leaf width and rhizome yield is depicted in Fig. 2. The coefficient of correlation was 0.59 at a significance level of 5%. The results demonstrated a moderate positive association between average leaf width and rhizome yield. The scattered dots along the fit line confirmed the significance of this relationship. The independent variable, average leaf width, can account for 34.4% of the variability in rhizome yield (Fig. 3D). The relationship between fresh leaf weight and rhizome yield is shown in Fig. 2. The coefficient of correlation was 0.64 at a significance level of 5%. The results indicated a strong positive relationship between fresh leaf weight and rhizome yield. The scattered dots near the fit line supported this significant correlation. The independent variable, fresh leaf weight, can explain 40.4% of the variability in rhizome yield (Fig. 3E).

The relationship between dry leaf weight and rhizome yield is depicted in Fig. 2. The coefficient of correlation was 0.68 at a significance level of 5%. The results demonstrated a strong positive association between dry leaf weight and rhizome yield. The scattered dots around the fit line further illustrated this strong relationship. The independent variable, dry leaf weight, can account for 46.0% of the variability in rhizome yield (Fig. 3F).

Table 3 Cost of rooftop ginger production (Treated)

Description	Per unit cost	Amount of the units	Amount (Taka)	Units in %
Soil and soil preparation	3.33tk/bag	15 bags	50	10.70
Bags	1.5 tk/bag	15 bags	22.5	4.80
Rhizome Seed Cost	150tk/kg	2 kg	300	64.17
Micronutrient Supplements	10tk/spray	3 sprays	30	6.42
Pesticides			40	8.56
Fertilizer use	Urea-30/kg TSP-30/kg Others-	Urea-225g TSP-235g Others-	25	5.35
Total variable cost			467.5	100

Total variable cost was calculated separately for the treatment and control. In case of control the cost of Micronutrient Supplements was not accountable.

3.3 Profitability Analysis

The current study estimated the average production cost of rooftop ginger to be Tk. 467.5. The entire expenditure was solely allocated to variable costs, a total of Tk. 467.5. The proportion of the overall cost was determined to be greatest for rhizome seed at 64.17%, succeeded by bags at 4.80%, pesticides at 8.56%, and micronutrient supplements at 6.42% among the various cost items (Table 3). In this study, there were no costs associated with soil, soil preparation, or land use.

Table 4 Profitability of rooftop ginger production

Description	Quantity (Treated)	Quantity (Control)
Total Variable Costs (TK)	467.5	437.5
Total Yield (kg)	3.6	2.6kg
Price per kg (TK)	175	175
Gross Return (TK)	630	455
Net Return (TK)	162.5	17.5
Benefit-Cost Ratio	1.34	1.04

The mean yield of rooftop ginger production under the specified conditions was 3.6 kg, as indicated in Table 4. The total return amounted to Tk. 630, whereas the average net return stood at Tk. 162.5. The Benefit-Cost Ratio (BCR) in relation to the total cost was determined to be 1.34 (Table 4). Where in case of control units, the total yield was 2.6 kg, the total return was Tk. 455, the variable cost was 467.5 taka and the BCR was 1.04.

4. DISCUSSION

The findings of this study reveal that micronutrient supplements can significantly enhance both the vegetative and reproductive growth parameters of ginger cultivated in rooftop bags. The treated plants exhibited superior plant height, leaf length, and rhizome yield performance compared to the control group. These results align with previous research emphasizing the critical role of micronutrients in improving plant health and the yield of ginger in field conditions (Sial et al., 2022; Shadap et al., 2018).

Treated plants showed greater plant height (49.93 cm vs. 41.11 cm), longer leaf lengths (21.12 cm vs. 18.09 cm), and higher rhizome yields (240.79 g vs. 176.75 g) compared to the control group. Positive trends were also observed in other parameters, such as leaf width, fresh leaf weight, and dry leaf weight, although these differences were not statistically significant. The statistically significant increase in rhizome yield in the treated group underscores the efficacy of micronutrient supplements to optimize nutrient availability in unconventional urban farming environments. This solves the problem mentioned by Chakraborty et al. (2021), who highlighted the challenges of micronutrient limitations in soils due to being frequently reused and intensive cultivation, which is common in rooftop cultivation.

Additionally, the strong correlation observed between tiller number, plant height, and rhizome yield (Fig. 2, 3A, 3B) suggests that improvements in vegetative growth directly influence reproductive output, supporting findings from prior studies on nutrient-plant dynamics (Korgaonkar et al., 2024; Adivappar & Naik, 2021). While the number of tillers, leaf width, fresh leaf weight, and dry leaf weight showed positive but statistically insignificant differences, the upward trend in these parameters suggests potential long-term benefits with optimized application strategies. For instance, higher leaf width and dry weight could contribute to improved photosynthetic efficiency, carbohydrate storage and biomass accumulation, further enhancing rhizome yield over extended periods (Ullah et al., 2024; Wei et al., 2020).

The use of foliar spray as a micronutrient source presents a novel and sustainable approach to addressing urban agricultural challenges. The profitability analysis further reinforces this method's viability, with a Benefit-Cost Ratio (BCR) of 1.34 demonstrating economic feasibility. This aligns with Acharya et al. (2019), who reported comparable profitability levels in ginger cultivation under traditional systems.

Our study also discusses the economic viability of this cultivation method, indicated by a calculated benefit-cost ratio (BCR). The BCR for this micronutrient supplement in ginger production was 1.34 which is greater than the control (1.04), suggesting that such interventions could be profitable. This is in line with findings by Rahman et al. (2022), who analyzed the profitability of ginger cultivation in Bangladesh, demonstrating substantial returns and BCRs as high as 3.1 with two buds transplanting. Similar economic benefits were observed in studies by Adhikari & Bhandari (2022), Adivappar & Naik (2021) and Poudel et al. (2016), which investigated the profitability of improved agricultural practices, confirming that strategic enhancements in cultivation methods, such as micronutrients supplement, can lead to considerable economic gains in urban agricultural settings.

5. CONCLUSIONS

Rooftop farming presents a promising solution for urban food security it faces some problems including nutrient shortages and limited soil volume. The findings of this study highlight the possibility of micronutrient supplements as an efficient way to improve ginger's yield and development in rooftop farming. Micronutrient supplements significantly improved ginger growth and yield, with notable increases in plant height, leaf length, and rhizome production. While some growth parameters showed positive but statistically insignificant effects, the strong correlation between vegetative growth and yield highlights the importance of micronutrients.

Furthermore, the economic analysis confirmed the profitability of this intervention, with a higher Benefit-Cost Ratio (BCR) compared to untreated plants, making it a cost-effective strategy for urban farmers. Still, further research is required to improve nutrient formulations, investigate long term impacts on soil, environment health and evaluate scalability among different crop varieties. In summary, integrating micronutrient supplements in rooftop ginger cultivation can play a pivotal role in enhancing crop productivity. This study lays the foundation for further exploration of micronutrient supplements in enhancing ginger yield.

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