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*Research Article*

# Zinc and boron micronutrients application enhance sweet corn productivity

**Hafith Furqoni [1,*], Erik Mulyana [2], Astryani Rosyad [3], Adrian Khairullah [4], Sofian Annas [4], and Suwarto [1]**

[1] Division of Plant Ecophysiology, Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University (Bogor Agricultural University), Jalan Meranti, Kampus IPB Dramaga, Bogor 16680, INDONESIA
[2] Division of Plant Production, Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University (Bogor Agricultural University), Jalan Meranti, Kampus IPB Dramaga, Bogor 16680, INDONESIA
[3] Division of Seed Science and Technology, Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University (Bogor Agricultural University), Jalan Meranti, Kampus IPB Dramaga, Bogor 16680, INDONESIA
[4] Fast track student of Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University (Bogor Agricultural University), Jalan Meranti, Kampus IPB Dramaga, Bogor 16680, INDONESIA
* Corresponding author (✉ hafithfurqoni@apps.ipb.ac.id)

## ABSTRACT

*Sweet corn (Zea mays L. var saccharata) is a valuable crop whose productivity depends not only on macronutrients but also on micronutrients such as zinc (Zn) and boron (B), which play essential roles in plant physiological processes. However, the effectiveness of foliar-applied micronutrients in sweet corn cultivation under tropical conditions remains insufficiently studied. This research aimed to evaluate the agronomic effectiveness of a micronutrient fertilizer containing Zn (5.46%) and B (3.59%) when combined with reference and reduced doses of NPK fertilizer. The experiment was conducted from February to May 2025 at the Sindangbarang Experimental Farm, IPB University. This experiment was conducted using a randomized complete block design with four treatments, namely control (no fertilizer), reference fertilizer, reference fertilizer + 1 dose of micronutrient fertilizer, and ¾ dose of reference fertilizer + 1 dose of micronutrient fertilizer, with six replications. Results showed that micronutrient application significantly enhanced vegetative growth and yield components compared to the control. The combination of reference NPK and one dose of micronutrient fertilizer produced the highest productivity, with a 78.8% increase over the control and a relative agronomic effectiveness (RAE) value of 114.5%, indicating a 1.14-fold improvement over the reference treatment. These findings suggest that integrating Zn and B into fertilization strategies can enhance sweet corn performance and support more efficient nutrient management in tropical agroecosystems.*

**Keywords**: crop yield improvement; foliar fertilization; micronutrient uptake; tropical field experiment; *Zea mays* physiology

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## INTRODUCTION

Sweet corn (*Zea mays* L. var Saccharata) is a valuable crop that is extensively grown for its sweet kernels and nutritional benefits. Its yield is affected by several agronomic factors, such as soil fertility and nutrient management (Gautam et al., 2025; Singh & Prasad, 2025). While macronutrients like nitrogen (N), phosphorus (P), and potassium (K) are essential for plant development (Sahoo et al., 2020), there is a growing recognition of the importance of micronutrients, especially zinc (Zn) and boron (B), in supporting physiological functions and enhancing yield (Ali et al., 2022; Usmani et al., 2025).

Zinc is essential for activating enzymes, synthesizing proteins, and forming chlorophyll (Dhaliwal et al., 2021; Tripathi et al., 2015; Younas et al., 2024), whereas boron is vital for the development of cell walls, reproductive growth, and the transportation of nutrients (Yu et al., 2002; Aquea et al., 2012). Deficiencies in these micronutrients can lead to stunted growth, poor pollination, and reduced yield (Iwai et al., 2006; Sarkar et al., 2007; Venugopalan et al., 2021). Foliar application of micronutrients has emerged as an effective strategy to enhance nutrient uptake and improve crop performance, especially under conditions where soil micronutrient availability is limited (Phuphong et al., 2018; Sree et al., 2024; Stewart et al., 2020).

Previous studies have demonstrated that the integration of micronutrient fertilizers with conventional NPK regimes can significantly improve growth parameters and yield components in maize (Awdalla et al., 2018; Randhawa et al., 2017; Verma et al., 2021). However, there has been limited investigation on the specific effects of Zn and B foliar application in sweet corn cultivation under Indonesian agroecological conditions.

The objective of this study was to evaluate the agronomic effectiveness of a micronutrient fertilizer containing Zn and B when applied in combination with standard and reduced doses of NPK fertilizer. The objectives were to assess its impact on vegetative growth, yield components, and overall productivity of sweet corn, and to determine its relative agronomic effectiveness compared to conventional fertilization practices.

## MATERIALS AND METHODS

### *Time and location of the study*

The study was conducted from February to May 2025 at the Sindangbarang Experimental Farm, Faculty of Agriculture, IPB University, Bogor, Indonesia. Post-harvest observations were carried out at the Plant Ecophysiology Laboratory, Department of Agronomy and Horticulture, Faculty of Agriculture, IPB University.

### *Experimental design*

The experiment employed a randomized complete block design (RCBD) with a single factor. Four micronutrient (Zn; B) fertilizer treatment levels were applied: control (no fertilizer), standard fertilizer, standard fertilizer + 1 dose of micronutrient fertilizer, and ¾ dose of standard fertilizer + 1 dose of micronutrient fertilizer. Each treatment was replicated six times, resulting in 24 experimental units. The micronutrient fertilizer used contained 5.46% Zn and 3.59% B.

### *Implementation method*

Land preparation was carried out by tilling the soil to a depth of 25 cm, followed by exposure to direct sunlight. Sweet corn seeds were planted by making holes using a dibble stick, with a planting distance of 75 cm × 25 cm. Each hole received two sweet corn seeds along with karbofuran. Thinning was performed at 2 weeks after planting (WAP), leaving one plant per hole.

The standard inorganic fertilizer dosage for corn was 300 kg ha$^{-1}$ urea, 200 kg ha$^{-1}$ SP-36, and 200 kg ha$^{-1}$ KCl. SP-36 was applied entirely at planting, while urea and KCl were applied in two splits: half at planting and half at 4 WAP. The specific fertilizer dosages for each treatment are presented in Table 1. Urea, SP-36, and KCl were applied in furrows to the right or left of the plant rows.

Table 1. Fertilizer dosage details in the evaluation of micronutrient inorganic fertilizer effectiveness.

| Treatment | Dose of micronutrient fertilizer (kg $ha^{-1}$) | Dose of Urea (kg $ha^{-1}$) | Dose of SP-36 (kg $ha^{-1}$) | Dose of KCl (kg $ha^{-1}$) |
|---|---|---|---|---|
| Control | 0 | 0 | 0 | 0 |
| Standard fertilizer | 0 | 300 | 200 | 200 |
| Standard + 1 dose of micro fertilizer | 12 | 300 | 200 | 200 |
| ¾ standard + 1 dose of micro fertilizer | 12 | 225 | 150 | 150 |

Micronutrient fertilizer was applied via foliar spraying. Applications were conducted four times at 14, 24, 34, and 44 days after planting (DAP). The dosage per application was 7.5 g per plot, equivalent to 7.5 g per 5 L of water for a 25 $m^2$ plot.

*Observations*

Vegetative observations included plant height, leaf number, and stem diameter, recorded at 4, 6, and 8 WAP. Measurements were taken from 10 randomly selected plants per plot. Corn was harvested at approximately 10–11 WAP, and yield components observed included ear weight with husk, ear weight without husk, ear length without husk, and ear diameter without husk. Productivity estimation was performed by harvesting ears from each plot (excluding border plants) and converting the yield to a per-hectare basis.

*Data analysis*

The data were analyzed statistically using analysis of variance (ANOVA) along with Duncan's Multiple Range Test (DMRT) at a significance level of 5%. Agronomic effectiveness of the micronutrient fertilizer was determined using the relative agronomic effectiveness (RAE) method (da Silva et al., 2024), calculated using the following formula:

$$\text{RAE (\%)} = \frac{\text{YaM} - \text{Yield of Control}}{\text{YrM} - \text{Yield of Control}} \text{ x } 100$$

Where RAE (%) is the relative agronomic effectiveness, YaM represents the yield of specific micronutrient fertilizer (ton $ha^{-1}$); YrM represents the yield from the reference.

## RESULTS AND DISCUSSION

### *Results*

Effect of micronutrient fertilizer on sweet corn growth

Micronutrient fertilizer application significantly influenced sweet corn plant height (Table 2). Observations indicated that plants receiving micronutrient fertilizer exhibited greater height compared to the control from early growth stages through the end of the vegetative phase at 8 weeks after planting (WAP). The application of one dose of micronutrient fertilizer, whether combined with the standard NPK or ¾ of the standard NPK dose, did not result in significant differences in plant height among treatments or compared to the standard NPK treatment alone.

Table 2. Height of sweet corn in the effectiveness trial of micronutrient fertilizers.

| Treatment | Plant height (cm) | | |
|---|---|---|---|
| | 4 WAP | 6 WAP | 8 WAP |
| Control | 72.9b | 117.1b | 163.2b |
| Standard fertilizer | 80.8a | 131.7a | 183.5a |
| Standard + 1 dose of micro fertilizer | 81.1a | 133.5a | 185.6a |
| ¾ standard + 1 dose of micro fertilizer | 84.5a | 137.1a | 188.7a |

*Note:* Numbers in the same column that are accompanied by the same letter show no significant difference based on Duncan's Multiple Range Test (DMRT) at a 5% significance threshold.

Micronutrient fertilizer also had a positive effect on stem diameter (Table 3). The combination of one dose of micronutrient fertilizer with either the standard NPK or ¾ NPK dose produced the best response in stem diameter from 4 to 8 WAP compared to the control. However, the response was not significantly different from the standard NPK treatment during the vegetative observation period.

Table 3. Stem diameter of sweet corn plants in the micronutrient fertilizer effectiveness trial.

| Treatment | Stem diameter (mm) | | |
|---|---|---|---|
| | 4 WAP | 6 WAP | 8 WAP |
| Control | 8.1b | 14.7b | 15.7b |
| Standard fertilizer | 9.8ab | 17.0a | 18.1a |
| Standard + 1 dose of micro fertilizer | 10.8a | 17.2a | 18.3a |
| ¾ standard + 1 dose of micro fertilizer | 10.8a | 17.4a | 18.5a |

*Note*: Numbers in the same column that are accompanied by the same letter show no significant difference based on Duncan's Multiple Range Test (DMRT) at a 5% significance threshold.

A positive response was also observed in leaf number (Table 4). The treatment combining ¾ NPK with one dose of micronutrient fertilizer resulted in the highest leaf count at 4 and 8 WAP. Additionally, this treatment showed a significantly higher leaf number than the control at 6 WAP.

Table 4. Leaf number of sweet corn plants in the micronutrient fertilizer effectiveness trial.

| Treatment | Leaf number | | |
|---|---|---|---|
| | 4 WAP | 6 WAP | 8 WAP |
| Control | 6.2b | 8.3b | 10.4c |
| Standard fertilizer | 6.4b | 9.1a | 11.4b |
| Standard + 1 dose of micro fertilizer | 6.4b | 9.2a | 11.4b |
| ¾ standard + 1 dose of micro fertilizer | 6.9a | 9.6a | 11.8a |

*Note:* Numbers in the same column that are accompanied by the same letter show no significant difference based on Duncan's Multiple Range Test (DMRT) at a 5% significance threshold.

Effect of micronutrient fertilizer on sweet corn yield components

Micronutrient fertilizer application positively affected ear length and ear diameter (Table 5). One dose of micronutrient fertilizer, whether combined with standard NPK or ¾ NPK, produced similar results for both parameters. These treatments significantly increased ear length and diameter compared to the control, although they were not significantly different from the standard NPK treatment.

Table 5. Ear length and ear diameter of sweet corn plants in the micronutrient fertilizer effectiveness trial.

| Treatment | Ear length (cm) | Ear diameter (mm) |
|---|---|---|
| Control | 17.2b | 44.10b |
| Standard fertilizer | 19.7a | 47.98a |
| Standard + 1 dose of micro fertilizer | 19.7a | 47.96a |
| ¾ standard + 1 dose of micro fertilizer | 19.4a | 48.46a |

*Note*: Numbers in the same column that are accompanied by the same letter show no significant difference based on Duncan's Multiple Range Test (DMRT) at a 5% significance threshold.

Positive responses were also observed in biomass weight, husked ear weight, and ear weight without husk (Table 6). The combination of one dose of micronutrient fertilizer with either standard NPK or ¾ NPK resulted in better yield components than the control. However, these combinations did not differ significantly from the standard NPK treatment in terms of biomass weight, husked ear weight, and ear weight without husk.

Table 6. Biomass weight, husked ear weight, and ear weight without husk of sweet corn plants in the trial on the effectiveness of micronutrient fertilizers.

| Treatment | Biomass weight (kg) | Husked ear weight (kg) | Ear weight without husk (kg) |
|---|---|---|---|
| Control | 0.203b | 0.211b | 0.164b |
| Standard fertilizer | 0.301a | 0.297a | 0.234a |
| Standard + 1 dose of micro fertilizer | 0.296a | 0.308a | 0.237a |
| ¾ standard + 1 dose of micro fertilizer | 0.275a | 0.309a | 0.236a |

*Note*: Numbers in the same column that are accompanied by the same letter show no significant difference based on Duncan's Multiple Range Test (DMRT) at a 5% significance threshold.

Micronutrient fertilizer application also improved plot weight and overall productivity of sweet corn (Table 7). Treatments combining standard NPK or ¾ NPK with one dose of micronutrient fertilizer yielded higher plot weights and productivity compared to the control. Nevertheless, these combinations did not show significant differences from the standard NPK treatment for these yield components.

Table 7. Plot weight and productivity of sweet corn plants in the micronutrient fertilizer effectiveness trial.

| Treatment | Plot weight (kg) | Productivity (ton $ha^{-1}$) |
|---|---|---|
| Control | 10.232b | 6.496b |
| Standard fertilizer | 17.275a | 10.968a |
| Standard + 1 dose of micro fertilizer | 18.297a | 11.616a |
| ¾ standard + 1 dose of micro fertilizer | 17.393a | 11.043a |

*Note*: Numbers in the same column that are accompanied by the same letter show no significant difference based on Duncan's Multiple Range Test (DMRT) at a 5% significance threshold.

Relative agronomic effectiveness (RAE)

Relative agronomic effectiveness is a measure used to assess the efficiency of fertilizers. A fertilizer is deemed agronomically effective if its RAE value is greater than 100. An RAE value greater than 100 indicates that the fertilizer enhances yield more than the increase achieved by the reference fertilizer compared to the control. The RAE analysis results for micronutrient fertilizer are presented in Table 8.

Table 8. Relative agronomic effectiveness (RAE) values of micronutrient fertilizer treatments.

| Treatment | RAE (%) |
|---|---|
| Control | - |
| Standard fertilizer | - |
| Standard + 1 dose of micro fertilizer | 114.48 |
| ¾ standard + 1 dose of micro fertilizer | 101.70 |

The calculated RAE values showed that the combination of micronutrient fertilizer with both standard NPK and ¾ NPK was agronomically effective, with values exceeding 100. The combination of one dose of micronutrient fertilizer with standard NPK yielded the highest RAE value, increasing yield by 1.14 times (114%) compared to the yield improvement from the reference treatment (standard NPK).

*Discussion*

The use of micronutrient fertilizers positively influenced all growth factors of sweet corn. This was evidenced by an increase in plant height ranging from 13.7% to 15.6% compared to the control treatment. Additionally, stem diameter increased by 16.7% to 18.0%, and leaf number rose by 10.0% to 14.2% relative to the control. The ideal growth of sweet corn relies on macronutrients like nitrogen (N), phosphorus (P), and potassium (K), but it is also greatly affected by micronutrients, especially zinc (Zn) and boron (B)

(Baseggio et al., 2021; Singh et al., 2024). Applying micronutrients through foliar methods has been demonstrated to improve plant growth and increase yield (Stewart et al., 2020). The need for micronutrients like Zn and B is especially critical during the plant's growth stages. Research has demonstrated that fertilizers containing micronutrients can improve corn growth and yield, with Zn and B playing key roles in photosynthesis and cellular metabolism (Mardhiana et al., 2021). Farrasati et al. (2021) support this by stating that applying Zn and B to the foliage boosts plant resilience against stress and enhances the availability of micronutrients, resulting in increased photosynthetic rates and higher crop yields.

Moreover, micronutrient fertilizer also improved yield components compared to the control. Ear length and diameter increased by 14.2% and 9.9%, respectively. Biomass weight, husked ear weight, and ear weight without husk increased by 45.8%, 46.4%, and 44.5%, respectively. Plot weight and overall productivity rose by 78.8% compared to the control. The sweet corn productivity observed in this study, which ranged from 10.968 to 11.616 ton $ha^{-1}$, considerably exceeds the average national sweet corn productivity in Indonesia of 8.31 ton $ha^{-1}$ (Budiono et al., 2023). This indicates that the right amount of fertilizer can achieve the yield genetic potential and even surpass typical growth parameters, as evidenced by the significant improvements observed across various yield components (Naik et al., 2020). This aligns with findings demonstrating that optimal fertilizer application, including micronutrients, can significantly enhance crop productivity and nutrient assimilation (Budiono et al., 2023).

However, the application of micronutrients did not show any significance with the standard ferlizier. This outcome suggests that while micronutrients are crucial for optimal sweet corn development, the standard NPK treatment already provides sufficient nutritional support to achieve comparable growth and yield metrics under the tested conditions (Budiono et al., 2023; Wu et al., 1993). This implies that while micronutrient supplementation can enhance various growth parameters, the baseline NPK application sufficiently addresses the plant's requirements for maximum yield expression in the given experimental setup (Ajibola et al., 2020).

The application of zinc (Zn) had a significant impact on sweet corn yield, particularly in enhancing plant growth and productivity. Zinc is an essential trace element that plays a crucial role in numerous physiological functions, such as chlorophyll production, the process of photosynthesis, and the efficiency of water utilization—all of which enhance corn yield (Barman et al., 2018; Wasaya et al., 2017). Several studies have shown that Zn-containing fertilizers enhance corn growth and productivity. For instance, the combination of ameliorants and NPK fertilizers with Zn not only improved soil fertility but also enhanced the growth and development of waxy corn grown on ultisol soils. This synergy between Zn and macronutrients promotes overall plant health (Harini et al., 2021). Additionally, foliar Zn application has been proven to boost vegetative growth in corn. The integration of NPK with organic fertilizers enhances nutrient uptake, including Zn, which contributes to better quality and yield in hybrid corn (Sudania et al., 2021).

Boron (B) also plays a significant role in sweet corn growth, as evidenced by various studies highlighting its contribution to plant health and yield (Ojha et al., 2023). Boron is essential for physiological processes and affects several key aspects of plant development. Application of boron fertilizer to the sweet corn variety BSA1 at a dose of 15 kg $ha^{-1}$ positively influenced flowering time for both male and female flowers and improved kernel quality (Kartina et al., 2023). Boron also supports tissue development and enhances the uptake of other nutrients, contributing to stronger cell bonding within the plant (Amissah et al., 2023). Its interaction with other nutrients influences plant metabolism, such as chlorophyll formation, which supports photosynthesis—a critical process for plant growth (Hawkesford et al., 2011). Studies have shown positive interactions between boron and macronutrients like nitrogen and phosphorus, which enhance nutrient absorption (Hasibuan et al., 2022).

Based on the relative agronomic effectiveness (RAE), the combination of micronutrient fertilizer with standard NPK yielded the highest value of 114.5%, indicating a 1.14-fold increase in yield compared to the improvement achieved by the reference treatment. This enhancement demonstrates the significant role of micronutrients, particularly Zn and B, in promoting plant growth and producing superior ears compared to the control treatment.

## CONCLUSIONS

The results of this study indicate that the application of standard NPK fertilizer combined with one dose of micronutrient fertilizer (containing 5.46% Zn and 3.59% B) effectively enhanced the growth and yield components of sweet corn. This treatment also improved yield performance compared to the control. Furthermore, the combination of standard NPK and one dose of micronutrient fertilizer was agronomically effective, as evidenced by the highest relative agronomic effectiveness (RAE) value of 114.5%, indicating a 1.14-fold increase in productivity compared to the reference treatment.

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