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The Influence of Zinc and Boron Application on Growth, Yield, Seed Quality, and Nutrient Content in Non-hybrid Corn

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ABSTRACT

Zinc (Zn) and Boron (B) are micronutrients required by plants in small amounts but play an important role in plant growth. Zn and B contents are also essential nutrients for human health. There has been no research on the effects of Zn and B as biofortification on the Srikandi variety corn (non-hybrid). This study aimed to determine the effect of Zinc and Boron spraying on growth, productivity, seed quality, and Zn and B content in the Srikandi variety. This experiment consisted of four treatments of Zinc and Boron spraying on leaves, namely (1) Zinc 0% + Boron 0%; (2) Zinc 0.5% + Boron 0.5%; (3) Zinc 1% + Boron 1%; (4) Zinc 2% + Boron 1.5%. The results showed that Zn and B applications significantly affected the growth, seed quality, and nutritional content of the Srikandi variety corn. Application of Zn 1% + B 1% was the best treatment for increasing the number of leaves, stover weight, seed germination and vigour, growth homogeneity, and Zn and B content in corn.

Keywords: Biofortification, boron, corn, nutrition, seed, zinc

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INTRODUCTION

Corn is one of the important food crops in Indonesia. Corn consumption as food in Indonesia continues to increase from 2021-2023, respectively, 2.7 kg cap^{-1} $year^{-1}$; 3.1 kg cap^{-1} $year^{-1}$; 3.6 kg cap^{-1} $year^{-1}$. Increased corn consumption must be accompanied by increased production to meet corn needs. According to Edy (2020), the Srikandi corn variety was one of the superior varieties that was quite popular in Indonesia because of its high productivity and superior nutritional value. This variety is included in the Quality Protein Maize (QPM) corn group, which has a higher content of the essential amino acids lysine and tryptophan than regular corn, making it useful for improving the nutritional quality of food and feed.

Zinc (Zn) and boron (B) are essential micronutrients that play an important role in corn plant growth and human health. Deficiencies of these two elements in plants reduce corn's nutritional quality, especially in the context of preventing stunting in children (Praharaj et al., 2021). Deficiencies of Zn and B cause stunted plant growth, decreased productivity, low grain quality, and low Zn, B, and protein content (Singh et al., 2020). Zn and B are micronutrients that play an important role in plant growth and production. Zn is important in various enzymatic reactions, nitrogen metabolism processes, energy transfer, and protein synthesis (Choukri et al., 2022; Kumar et al., 2019; Singh et al., 2020). Zn deficiency in plants is seen in the form of symptoms of stunted growth, chlorosis, shrunken leaves, and empty grains (Suganya et al., 2020). In corn plants, Zn application can increase growth and yield (Basavanneppa et al., 2020; Hisham et al., 2021; Mohsin et al., 2014; Palai et al., 2018; Stepić et al., 2022).

Boron is one of the nutrients that also plays an important role in plant growth and reproduction. B played a role in carbohydrate metabolism and sugar transport, plant cell wall formation, lignification, RNA metabolism, indole acetic acid (IAA) metabolism and pollen tube growth (Nogueira et al., 2019; Santra et al., 2024). B plays an important role in increasing corn yields, as it significantly affects the number of seeds per cob, cob length, and harvest yield (Almosawy et al., 2019). B applied with plant growth regulators increased corn yields (Gurjar et al., 2020). Bayar et al. (2024) reported that spraying corn plants with 1% B increased plant height, leaf area, yield, and 1000-grain weight. B deficiency in plants caused the cessation of terminal shoot growth, death of young leaves, inhibition of sugar transport, and formation and germination of pollen. Seeds and grains were also reduced if the boron supply was hampered (Jolli et al., 2020).

In humans, Zn is needed to boost the immune system. Zn played an important role in enzyme activation and body metabolism (Suganya et al., 2020). Zn deficiency in children disrupts physical growth or stunting, the immune system, learning ability, and the development of cancer cells (Abdoli & Esfandiari, 2017; Boonchuay et al., 2013; Shori et al., 2019). B is a mineral that plays an important role in several human biological processes. B showed various pleiotropic effects, ranging from anti-inflammatory and antioxidant effects to the immune system, affecting bone growth and central nervous system function, relieving rheumatic symptoms, affecting hormone function, and reducing the risk of several types of cancer (Meacham et al., 2010; Nielsen, 2014).

Zn and B in plants plays role in photosynthesis, protein synthesis, chlorophyll, carbohydrates, flowering regulation, and reducing kernel abortion (Kumar et al., 2019).

Singh et al. (2020) revealed that applying Zn and B increased plant height, stem circumference, cob length, and corn grain index. The combined application of Zn and B resulted in higher growth because both elements play important roles in the process of assimilation rate and metabolic activity in plants (Sharma & Mehera, 2022). Mohsin et al. (2014) suggested that the combined application of Zn, such as seed priming (2.0%) and foliar spraying (2.0%), can improve the performance of hybrid corn. Foliar application in corn at concentrations of approximately 0.5–1.5% $ZnSO_4$ and H_3BO_3 has been shown to improve nutrient status and seed quality without causing toxicity (Mohsin et al., 2014; Suganya et al., 2020; Singh et al., 2020). According to Fageria et al. (2009), foliar fertilisation is often more economical, rapidly absorbed, and effective in improving plant nutrient status compared to several other approaches. Based on the literature study, we want to know the highest Zn and B content from the application of a combination of Zn and B on the Srikandi variety corn that we have compiled.

MATERIALS AND METHODS

The research was conducted from May-September 2023. Field trials were conducted at the Lampung State Polytechnic Experimental Garden. Seed quality testing was conducted at the Seed and Plant Breeding Laboratory, Faculty of Agriculture, Lampung University, Indonesia. Zn and B content analysis was conducted at the Integrated Laboratory and Technology Innovation Centre, Lampung University. The experiment was conducted in a Randomised Block Design (RBD) consisting of 4 treatments with 3 replications. The treatments were a combination of Zn and B, namely (1) Zn 0% + B 0% (control); (2) Zn 0.5% + B 0.5%; (3) Zn 1% + B 1%; (4) Zn 1.5% + B 1.5%.

Plant Preparation

Local corn variety Srikandi Ungu is planted with a spacing of 0.7 m x 0.2 m. Seed planting was done by digging holes with 2 corn seeds per planting hole. Fertilisation was given with the respective doses: 150 kg/ha urea, 100 kg/ha SP36 (Phosphate 36%), 100 kg/ha KCl. KCl and Phosphate fertilisers were given entirely one week after planting. Urea fertiliser was given 3 times at the 7th, 21st, and 45th days after planting. The soil used had a pH of 8.32 with a Nitrogen content of 0.10%, P = 193.55 ppm, K = 11.55 ppm, Zn = 53.27 ppm, and B = 77.76 ppm.

Application of Zn and B

The chemicals $ZnSO_4.7H_2O$ and H_3BO_3 were used as sources of Zn, and B. Zn and B were applied by spraying twice, namely at 30 and 50 days after planting (Singh et al., 2020).

Harvesting was carried out when the corn plants were 87 days after planting or when the corn had reached physiological maturity.

Observation Variable

The variables observed in this study were plant growth, harvest yield, seed quality, and zinc and boron content. Plant height was measured from the root neck to the tip of the highest leaf. The number of leaves counted was the number of corn leaves that had opened perfectly. Chlorophyll content in leaves was measured using a Chlorophyll Content Meter (CCM) brand Opti Sciences type CCM-200. The weight of cobs with and without husks, the number of rows per cob, the number of seeds per row, and the number of seeds in one cob were measured at harvest time, 87 days after planting. Physiological quality was measured according to the 2021 International Seed Testing Association guidelines. The Zn and B content in corn seeds was analysed using the Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) instrument. Measurements were carried out on ten sample plants per experimental plot.

Data Analysis

The data obtained were analysed for variance, followed by the Least Significant Difference test at α 5%. Data analysis was carried out using the R Studio data processing programme.

RESULTS AND DISCUSSION

Effect of Zn and B Spraying on Plant Growth

The application of Zn and B increased the number of leaves and stover the weight. The application of Zn 1% + B 1% was the best treatment in increasing the growth of Srikandi variety corn plants compared to other treatments on the variables of the number of leaves and the wet and dry stover weight in Table 1.

Table 1
Effect of Zn and B spraying on the growth of Srikandi variety corn

Treatment	PH (cm)	NL	TLA (cm^2)	CCI	CC ($\mu M\ m^{-2}$)	WSW (g)	DSW (g)
Control	237.2^a	14.10^c	438.10^a	32.80^a	436,3^a	379.3^d	132.5^c
Zn 0.5% + B 0.5%	248.5^a	14.75^b	489.06^a	36.51^a	463,4^a	592.7^{bc}	219.8^{ab}
Zn 1% + B 1%,	260.4^a	15.17^a	500.98^a	34.06^a	446,6^a	615.5^a	257.8^a
Zn 1.5% + B 1.5%	239.2^a	14.58^b	530.51^a	32.89^a	437,6^a	503.3^c	188.7^{bc}

Note. [1]Numbers followed by the same letter do not differ based on the LSD test at 5% levels. PH = Plant Height; NL = Number of Leaves; TLA = Total Leaf Area; CCI = Chlorophyll Content Index; CC = Chlorophyll Content; WSW = Wet Stover Weight; DSW = Dry Stover Weight

The increase in plant growth caused by applying Zn and B is evident from increased in chlorophyll content, the maximum number of leaves, and accumulation of dry matter in plants. This is supported by Tavallali (2017), who stated that the application of Zn and B had a synergistic effect in increasing plant dry weight, photosynthesis, and chlorophyll content. The application of Zn and B simultaneously provides higher growth results because both elements play an important role in the process of assimilation rate and metabolic activity in plants (Sharma & Mehera, 2022). The increase of Zn and B content was due to the influence of metabolic activity and enzymes that increase photosynthesis, leading to increased vegatative plant growth (Faiyad et al., 2023; Kumar et al., 2019). In this study, the insignificance of chlorophyll may have been caused by the accumulation of chlorophyll having been used optimally in increasing the number of leaves and stover weight of corn during the observation period.

Effect of Zn and B Spraying on Yield

The application of Zn and B to the Srikandi corn variety did not differ significantly from the control in terms of the productivity variables of corn cobs and kernels (Table 2). However, Srikandi variety corn is a superior type of Indonesian corn that has high productivity far above the average national corn productivity. This condition indicates that the increase in source capacity (photosynthesis and vegetative biomass) was not offset by an increase in sink strength during the generative phase, such as grain number and filling capacity. In the genetically high-yielding Srikandi variety, the sink potential may have approached its physiological limit, resulting in additional assimilates being allocated more to vegetative tissues, reflected in the relatively unchanged harvest index. This phenomenon is consistent with reports that micronutrient responses are often stronger in the vegetative phase and plant physiological quality compared to quantitative yield increases, especially when there is no severe nutrient deficiency (Singh et al., 2020; Sharma & Mehera, 2022). Based on the adaptation test by Wahid et al. (2022), Srikandi corn had high adaptation to dry land

Table 2
Effect of Zn and B spraying on the production of Srikandi variety corn

Treatment	Cob Fresh Matter with Husk (g)	Cob Fresh Matter without Husk (g)	Row per Cob (rows)	Seed per Row (seeds)	Seed per Cob (seeds)	1000 Seed Weight (g)
Zn 0% + B 0%	246.2[a]	204.1[a]	13.33[a]	27.0[a]	359.33[a]	258.70[a]
Zn 0.5% + B 0.5%	289.3[a]	237.4[a]	15.22[a]	29.0[a]	444.78[a]	271.37[a]
Zn 1% + B 1%,	290.3[a]	249.2[a]	16.11[a]	32.9[a]	531.37[a]	264.29[a]
Zn 1.5% + B1.5%	230.3[a]	189.1[a]	14.11[a]	27.1[a]	380.85[a]	242.91[a]

Note. [2]Numbers followed by the same letter do not differ based on the LSD test at the 5% level with higher productivity compared to other new superior corn varieties, namely Gumarang, Lamuru, and Bisma. Although the application of Zn and B to Srikandi corn plants did not affect corn yields, this variety already had higher yields than other corn varieties. In addition, the application of Zn and B to the Srikandi variety corn affected other parameters, such as growth (see Table 1), seed quality (see Table 3), and corn nutrition (see Table 4). The results align with the research of Singh et al. (2020), which explains that applying 1% Zinc and 1% Boron increases the diameter of the cob, seeds per row, rows per cob, and seed index.

Zinc is a micronutrient needed in metabolic activities that play a role in ensuring the quality of plant productivity (Tondey et al., 2022). Zinc played a role in carbohydrate metabolism, protein synthesis, and the regulation of auxin synthesis (Kumar et al., 2019). Boron helps the development of fruits and seeds, sugar transport, and hormone development (Kumar et al., 2019). John et al. (2011) revealed that the application of Boron to plants has an important effect on transporting sugar in photosynthesis, increasing flower production, fruit ripening, seed retention and development. Kumar et al. (2019) reported that spraying sweet corn with 0.3% B increased plant height, dry weight, and plant height growth rate. In the production attribute, boron increased the number of cobs per plant, the number of seeds per cob, the number of rows per cob, the seed index, and production.

Effect of Zn and B Spraying on Seed Quality

Seed quality was improved by the application of Zn 1% + B 1%. The application of Zn 1% + B 1% and Zn 1.5% + B 1.5% increased the percentages of seed vigour and growth homogeneity of the Srikandi variety corn. In addition, seed germination was also improved by application of Zn 1% + B1% (Table 3). Germination was an important phase to ensure optimal plant production and productivity (Tondey et al., 2022). In addition, germination was also an important stage in determining whether the seeds planted would have strong vigour and viability (Sedghi et al., 2013). The application of Zinc and Boron interacts with each other in the germination process.

Table 3
Effect of Zn and B spraying on the quality of Srikandi variety corn seeds

Treatment	Germination (%)	Vigour Index (%)	Growth Homogeneity (%)	Growth Speed (% day-1)	Maximal Potential Growth (%)
Zn 0% + B 0%	80[b]	78[b]	80[b]	17.3[a]	96[a]
Zn 0.5% + B 0.5%	86[b]	84[b]	86[b]	17.1[a]	98[a]
Zn 1% + B 1%,	98[a]	98[a]	98[a]	19.6[a]	100[a]
Zn 1.5% + B1.5%	82[b]	82[a]	82[a]	16.4[a]	98[a]

Note. [3]*Numbers followed by the same letter do not differ based on the LSD test at the 5% level*

The concentration of Zinc given to plants affects germination (Basha & Selvaraju, 2015). The application of Zn 1% + B 1% had the highest vigour index, germination power, and growth homogeneity of 98%. Lemes et al. (2015) reported that providing Zn increased shoot length by 9.3% and root length by 5.1%.

According to Ahmad et al. (2009), Zn has functions related to the strength and development of cell walls, seed development, hormone development, and is important in plant growth, such as in the development of leaves and leaf buds. Meanwhile, Zn increased metabolic activity and helped the growth of plant embryos during germination (Deepika, 2015). Zinc also played a role in protein synthesis, which played a role in good seed development, germination power, and high seed vigour index (Geetharani et al., 2008).

Abdoli & Esfandiari (2017) revealed that high Zn content in seeds can increase the vigour index and germination rate compared to seeds with low Zn content. The results showed a relationship between Zn content and germination; seeds containing high Zn significantly increased the percentage of root germination by 10.1% and the seedling vigour index by 26%. Zn application through leaves had been shown to increase Zn content in seeds more than Zn application in soil (Suganya et al., 2020).

Effect of Zn and B Spraying on Zn and B Corn Nutrient Content

The application of Zn and B increased the Zn content in the Srikandi variety corn. However, only the concentration of 1% Zn + 1% B also increased the B content in corn; other Zn and B treatments even reduced the B content (Table 4). According to Pawlowski et al. (2019) reported that corn with high Zn levels caused B levels in leaves and seeds to decrease, while in low Zn treatment, the opposite effect occurred. Excessive doses of Zn application also caused a decrease in B levels in corn leaves in greenhouses, although field experiments did not show any relationship between Zn application and B levels (Aref, 2012).

Table 4
Effect of Zn and B spraying on Zn and B content of Srikandi variety corn

Treatment	Zn Content in Corn (mg kg-1)	Boron Content in Corn (mg kg-1)
Zn 0% + B 0%	22.80[c]	0,49[b]
Zn 0.5% + B 0.5%	58.10[a]	0,07[d]
Zn 1% + B 1%,	35.48[b]	0,99[a]
Zn 1.5% + B1.5%	41.20[b]	0.39[c]

Note. [4]*Numbers followed by the same letter do not differ based on the LSD test at the 5% level*

CONCLUSION

Application of Zn 1% + B 1% on Srikandi variety corn plants was the best treatment in increasing growth through increasing the number of leaves and stover weight. Although the application of Zn + B did not increase yields, the application of Zn 1% + B 1% improved seed quality by increasing germination, seed vigour and growth homogeneity. In addition, the application of Zn 1% + B 1% also increased the Zn and B content of corn.

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