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Effect of Different Levels of Zinc and Boron Fertilization on Growth and Yield of Wheat

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ABSTRACT: A field experiment was conducted to evaluate the effects of zinc (Zn) and boron (B) fertilization on the growth and grain yield of wheat (BARI Gom-26). The experiment followed a randomized complete block design (RCBD) with three replications, comprising four foliar Zn levels (0, 0.02, 0.04, and 0.06%) and four soil-applied B levels (0, 0.5, 1.0, and 1.5 kg ha^{-1}). Growth, yield components, and grain yield were significantly influenced by both micronutrients. Among the individual Zn treatments, 0.04% Zn produced the tallest plants (80.26 cm) and the highest grain yield (2.73 t ha^{-1}), while the control recorded the lowest values. Similarly, the application of 1.0 kg B ha^{-1} resulted in the maximum plant height (80.02 cm) and grain yield (2.79 t ha^{-1}). Significant interaction

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effects were also observed, with the combined application of 0.04% Zn and 1.0 kg B ha^{-1} producing the highest plant height (83.56 cm) and grain yield (3.27 t ha^{-1}). In contrast, the control treatment without Zn and B showed the poorest performance. The findings indicate that balanced application of Zn and B, particularly 0.04% Zn and 1.0 kg B ha^{-1}, effectively enhances wheat growth and productivity, with boron exerting a greater influence on yield than zinc.

Keywords: *Micronutrients; Grain yield; Foliar application; Growth attributes; Yield components; BARI Gom-26.*

Introduction

Wheat (*Triticum aestivum* L.) is one of the world's most important cereal crops and ranks second after rice in Bangladesh (UNDP and FAO, 1999). Globally, it is a major source of carbohydrates and vegetable protein for human nutrition. In 2013, world wheat production reached 713 million tons, making it the third most-produced cereal after maize and rice. In Bangladesh, wheat contributes about 15–20% of the staple cereal food and occupies the second position among food crops (Rahman, 1980). The country produces about 1.30 million metric tons of wheat from 1.06 million acres with an average yield of 3.03 t ha^{-1} (BBS, 2014). With increasing population and growing food demand, improving wheat productivity has become essential for ensuring food security in Bangladesh. Balanced fertilizer application is indispensable for sustainable crop production. Besides macronutrients, micronutrients such as zinc (Zn) and boron (B) are essential for plant growth, metabolism and yield (Brady and Weil, 2002). Although required in small amounts, micronutrients regulate numerous physiological and biochemical processes, including enzyme activation, photosynthesis and protein synthesis (Ashikuzzaman et al., 2024). Their availability in soil is influenced by pH, organic matter, redox potential and soil mineral composition. Continuous cropping, intensive cultivation and imbalanced fertilizer use have increased micronutrient deficiencies in Bangladesh soils. Similar deficiencies are widespread in many Asian countries due to calcareous soils, high soil pH, low organic matter and excessive use of NPK fertilizers (Narimani et al., 2010). Among the micronutrients, zinc and boron are particularly important for wheat production (Hossain et al., 2024). Both nutrients participate in photosynthesis, respiration, nitrogen metabolism and several biochemical pathways essential for plant growth (Akca and Taban,

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2024). Zinc acts as a structural and regulatory component of many enzymes involved in protein synthesis, energy production, auxin metabolism, cytochrome synthesis and ribosome stabilization (Rahman et al., 2024). Zinc fertilization also increases grain Zn concentration and helps reduce Zn deficiency in humans while mitigating boron toxicity in plants (Aslam et al., 2014). Boron is equally essential for plant growth and reproductive development. It is involved in carbohydrate metabolism, protein synthesis, pollen germination, seed and cell wall formation (Vitosh et al., 1997). Boron also promotes cell elongation, sugar translocation, meristem development and nutrient transport from roots to shoots (Rehem et al., 1998). Adequate boron enhances root growth, fruit setting, grain formation and amino acid accumulation. However, information on boron management in wheat under Bangladesh conditions remains limited (BINA, 1993). Deficiency of zinc and boron is common in Bangladesh soils, particularly in neutral and calcareous soils (Graham et al., 1992). Zinc deficiency causes poor growth, interveinal chlorosis, necrosis and substantial yield reduction (Throne, 1957), while nearly 50% of cereal-growing soils worldwide are considered zinc deficient (Gibbson, 2006). Boron deficiency impairs cell wall formation, induces male sterility, reduces grain set and ultimately lowers wheat yield (Jahiruddin et al., 1992). Several studies have reported significant improvements in wheat growth and yield following Zn and B application (Torun et al., 2001). Wheat genotypes also vary considerably in their response to boron deficiency and toxicity (Rerkasem and Jamjod, 1999). Considering the widespread deficiencies of zinc and boron in Bangladesh soils and their significant influence on wheat productivity, the present study was undertaken to evaluate the effects of zinc and boron on the growth and yield of wheat.

Objectives

- To determine the optimum doses of zinc (Zn) and boron (B) for the growth and yield of wheat.
- To evaluate the individual effects of zinc and boron on wheat growth and yield under different micronutrient levels.
- To assess the interaction effects of zinc and boron on wheat growth and yield.

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Materials and Methods

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, during the Rabi season (October 2024 to February 2025). The experimental site belongs to the Madhupur Tract (AEZ-28) with Deep Red Brown Terrace Soil (Tejgaon series). The soil was silty clay in texture with a pH of 5.6. The wheat variety BARI Gom-26 was used as the test crop. The land was prepared by conventional tillage practices, and recommended intercultural operations were carried out throughout the growing season.

Experimental Design and Crop Management

The experiment was laid out in a two-factor factorial Randomized Complete Block Design (RCBD) with three replications. Each plot measured 2 m × 2 m.

The treatment factors were:

Factor A (Zinc levels):

- Zn_0 = Control
- Zn_1 = 0.02% Zn foliar spray
- Zn_2 = 0.04% Zn foliar spray
- Zn_3 = 0.06% Zn foliar spray

Factor B (Boron levels):

- B_0 = Control
- B_1 = 0.5 kg B ha^{-1}
- B_2 = 1.0 kg B ha^{-1}

B_3 = 1.5 kg B ha^{-1}

Table 1. Treatment combinations

Zn_0B_0	Zn_0B_1	Zn_0B_2	Zn_0B_3
Zn_1B_0	Zn_1B_1	Zn_1B_2	Zn_1B_3
Zn_2B_0	Zn_2B_1	Zn_2B_2	Zn_2B_3
Zn_3B_0	Zn_3B_1	Zn_3B_2	Zn_3B_3

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Fertilizers were applied following the Fertilizer Recommendation Guide (BARC, 2012). Urea, triple superphosphate (TSP), muriate of potash (MoP) and gypsum were used as sources of N, P, K and S, respectively. All P, K, S, B and half of the nitrogen were applied during final land preparation, while the remaining nitrogen was top-dressed before the booting stage. Zinc was applied as zinc sulphate monohydrate ($ZnSO_4 \cdot H_2O$) through foliar spray according to the treatment levels.

Data Collection

Five plants were randomly selected from each plot to record plant height (cm), spike length (cm), grains spike^{-1}, 1000-grain weight (g) and grain yield (t ha^{-1}). Grain yield was determined from the central 1 m^2 area of each plot and converted into t ha^{-1}.

Soil Analysis

Composite soil samples (0–15 cm depth) were collected before land preparation and analyzed at the Soil Resource Development Institute (SRDI), Dhaka. Soil properties including texture, pH, organic matter, total nitrogen, available phosphorus, exchangeable potassium and available sulphur were determined using standard analytical procedures.

Statistical Analysis

The recorded data were subjected to analysis of variance (ANOVA) using the MSTAT-C statistical package, and treatment means were compared at the 5% level of significance.

Results and Discussion

Effect of Zinc on Growth and Yield of Wheat

Zinc application significantly influenced all growth and yield parameters of wheat. Plant height, spike length, grains spike^{-1}, 1000-grain weight and grain yield increased with increasing Zn levels up to 0.04% Zn (Zn_2), after which no further significant improvement was observed. The tallest plants (80.26 cm), longest spikes (14.91 cm), highest number of grains spike^{-1} (50.92), maximum 1000-grain weight (47.58 g) and highest grain yield (2.73 t ha^{-1}) were obtained from Zn_2, whereas the lowest values were recorded in the control treatment (Zn_0) (Table 2 & Figure 1). Similar findings were reported by Zeidan et al. (2010), Ali et al. (2009), Torun et al. (2001), Grewal et al. (1997) and Seilsepour (2007).

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Table 2. Effect of Zinc on Growth and Yield of Wheat

Treatments	Plant height (cm)	Spike length (cm)	No. of grains Spike^{-1}	1000 grain weight (g)	Yield (t ha^{-1})
Zn_0 = control	77.73^{b}	14.15^{b}	46.92^{b}	44.35^{b}	2.30^{b}
Zn_1 = 0.02% Zn	78.29^{ab}	14.70^{ab}	49.73^{a}	46.72^{a}	2.61^{a}
Zn_2 = 0.04% Zn	**80.26^{a}**	**14.91^{a}**	**50.92^{a}**	**47.58^{a}**	**2.73^{a}**
Zn_3 = 0.06% Zn	79.41^{ab}	14.58^{a}	50.73^{a}	47.25^{a}	2.71^{a}

Values in a column followed by a common letter are not significantly different at $p < 0.05$

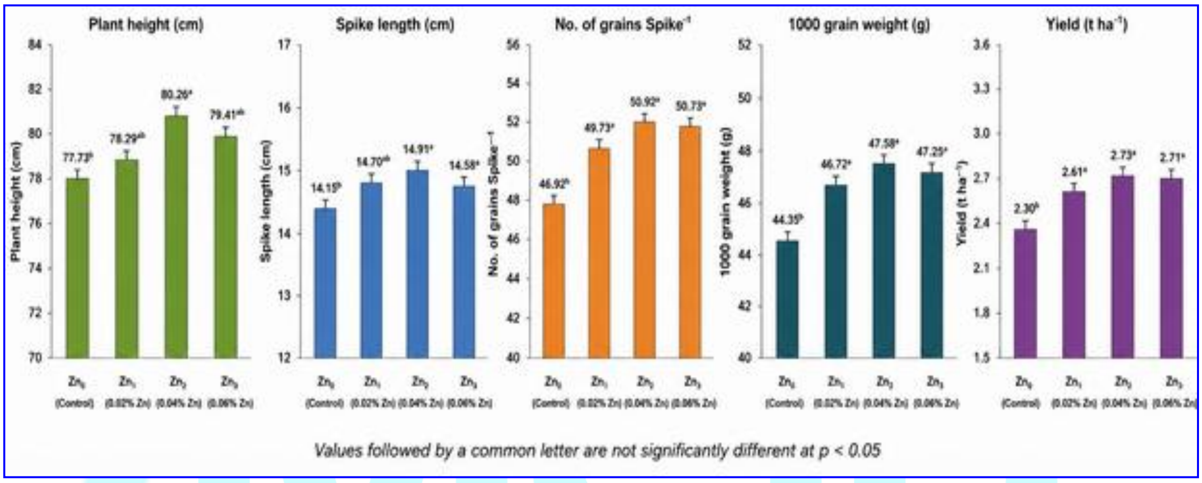

Figure 1. Effect of Zinc on Growth and Yield of Wheat

Effect of Boron on Growth and Yield of Wheat

Boron application significantly improved wheat growth and yield. The application of 1.0 kg B ha^{-1} (B_2) produced the tallest plants (80.02 cm), longest spikes (15.27 cm), highest grains spike^{-1} (52.25), greatest 1000-grain weight (47.44 g) and maximum grain yield (2.79 t ha^{-1}). The control treatment (B_0) consistently recorded the lowest values. Grain yield declined slightly at the highest boron dose (1.5 kg ha^{-1}), indicating possible adverse effects of excessive boron (Table 3 & Figure 2). These findings agree with those of Mandal and Das (1988), Mete et al. (2005), Soylu et al. (2005) and Jahiruddin et al. (1995).

Table 3. Effect of Boron on Growth and Yield of Wheat

Treatments	Plant height (cm)	Spike length (cm)	No. of grains Spike^{-1}	1000 grain weight (g)	Yield (t ha^{-1})
B_0 = control	76.85^{b}	14.22^{b}	47.70^{b}	46.49^{a}	2.35^{b}
B_1 = 0.5 kg	78.43^{ab}	14.43^{b}	50.18^{ab}	46.91^{a}	2.63^{a}
B_2 = 1.0 kg	**80.02^{a}**	**15.27^{a}**	**52.25^{a}**	**47.44^{a}**	**2.79^{a}**
B_3 = 1.5 kg	79.21^{a}	14.82^{ab}	50.45^{ab}	47.21^{a}	2.71^{a}

Values in a column followed by a common letter are not significantly different at $p < 0.05$

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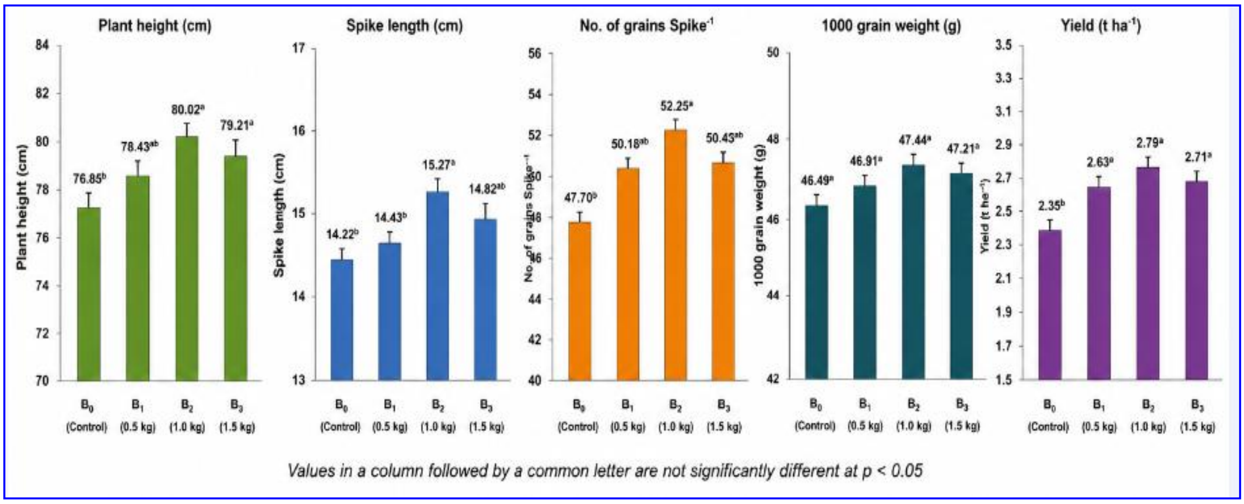

Figure 2. Effect of Boron on Growth and Yield of Wheat

Interaction Effect of Zinc and Boron

The interaction between zinc and boron significantly affected all measured growth and yield attributes. The combined treatment Zn_2B_2 (0.04% Zn + 1.0 kg B ha^{-1}) produced the highest plant height (83.56 cm), spike length (15.71 cm), grains spike^{-1} (54.87), 1000-grain weight (52.23 g) and grain yield (3.27 t ha^{-1}). In contrast, the control combination (Zn_0B_0) recorded the lowest values for all parameters, including the lowest grain yield (1.93 t ha^{-1}) (Table 4 & Figure 3). The results indicate that the combined application of zinc and boron exerted a synergistic effect on wheat growth and productivity (Table 4 & Figure 3). Similar observations were reported by Ali et al. (2009), Arif et al. (2006), Habib (2009) and Ziaeyan and Rajaie (2009).

Table 4. Interaction Effect of Zinc and Boron on Growth and Yield of Wheat

Treatments combination		Plant height (cm)	Spike length (cm)	No. of grains spike^{-1}	1000 grain weight (g)	Yield (t ha^{-1})
Zinc	Boron					
Zn_0 (Control)	B_0 = Control	75.69^{d}	13.77^{c}	45.40^{c}	45.40^{b}	1.93^{d}
Zn_0 (Control)	B_1 = 0.5 kg	76.93^{bcd}	13.79^{c}	45.41^{c}	44.43^{b}	2.23^{bcd}
Zn_0 (Control)	B_2 = 1.0 kg	78.45^{bcd}	14.15^{bc}	46.40^{bc}	45.47^{b}	2.83^{abc}
Zn_0 (Control)	B_3 = 1.5 kg	78.07^{bcd}	13.99^{c}	45.45^{c}	45.43^{b}	2.57^{abcd}
Zn_1 (0.02% Zn)	B_0 = Control	75.91^{bcd}	14.38^{abc}	46.47^{bc}	45.73^{b}	2.53^{abcd}
Zn_1 (0.02% Zn)	B_1 = 0.5 kg	79.70^{abcd}	14.40^{abc}	46.80^{bc}	45.93^{b}	2.74^{abc}
Zn_1 (0.02% Zn)	B_2 = 1.0 kg	81.43^{ab}	14.69^{abc}	50.60^{abc}	46.53^{ab}	2.83^{abc}
Zn_1 (0.02% Zn)	B_3 = 1.5 kg	76.20^{cd}	14.62^{abc}	51.73^{abc}	46.63^{ab}	2.80^{abc}
Zn_2 (0.04% Zn)	B_0 = Control	77.59^{cd}	14.83^{abc}	50.60^{abc}	46.80^{ab}	2.20^{cd}
Zn_2 (0.04% Zn)	B_1 = 0.5 kg	81.47^{ab}	14.95^{abc}	52.53^{ab}	46.87^{ab}	2.57^{abcd}
Zn_2 (0.04% Zn)	B_2 = 1.0 kg	83.56^{a}	15.71^{a}	54.87^{a}	52.23^{a}	3.27^{a}
Zn_2 (0.04% Zn)	B_3 = 1.5 kg	80.29^{abc}	15.55^{ab}	53.13^{ab}	49.03^{ab}	2.67^{abcd}
Zn_3 (0.06% Zn)	B_0 = Control	76.03^{cd}	15.01^{abc}	52.40^{abc}	47.20^{bc}	2.77^{bcd}
Zn_3 (0.06% Zn)	B_1 = 0.5 kg	77.80^{bcd}	15.01^{abc}	52.60^{ab}	47.27^{ab}	2.73^{abc}
Zn_3 (0.06% Zn)	B_2 = 1.0 kg	83.36^{a}	15.22^{abc}	53.13^{ab}	47.43^{ab}	3.00^{ab}
Zn_3 (0.06% Zn)	B_3 = 1.5 kg	80.24^{abcd}	15.03^{abc}	53.07^{abc}	47.40^{ab}	2.83^{abc}

Values in a column followed by a common letter are not significantly different at $p < 0.05$

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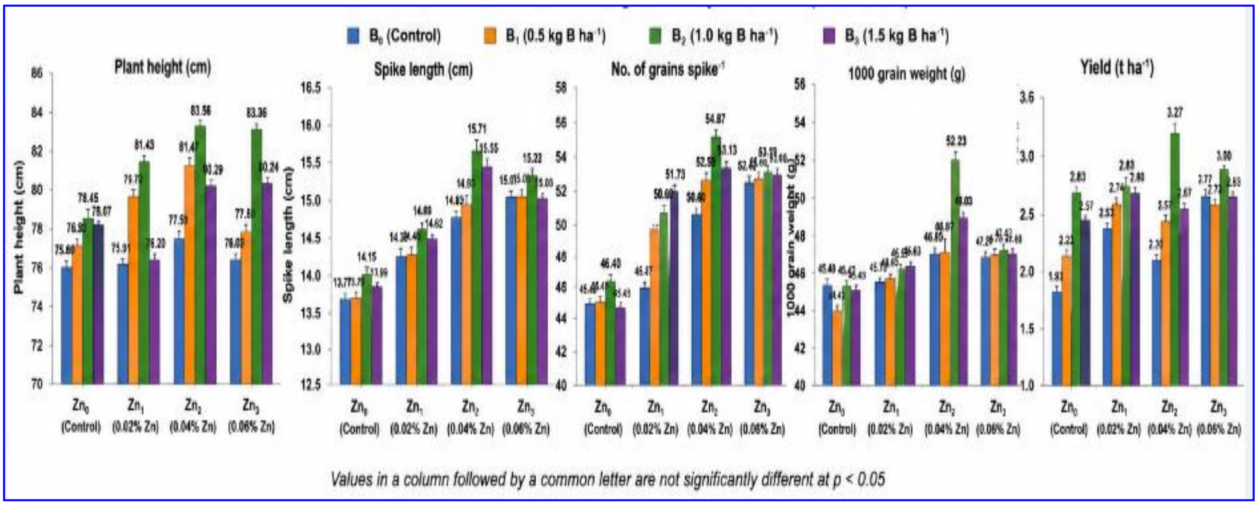

Figure 3. Interaction Effect of Zinc and Boron on Growth and Yield of Wheat

Conclusion

The study demonstrated that both zinc and boron significantly enhanced the growth and yield of wheat. Among the individual treatments, 0.04% Zn and 1.0 kg B ha^{-1} were the most effective doses. Their combined application (Zn_2B_2) produced the highest grain yield (3.27 t ha^{-1}) and superior yield-contributing characters, indicating that balanced application of zinc and boron is essential for maximizing wheat productivity under the experimental conditions.

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