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Effect of Foliar Application of Zinc and Boron on the Growth and Yield of Wheat

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ABSTRACT

The field experiment was conducted from November, 2022 to March, 2023 at the Sher-e-Bangla Agricultural University research farm in Dhaka, Bangladesh to evaluate the effect of foliar application of Zn and B on wheat. The experiment utilized a Randomized Complete Block Design with three replications, using BARI Gom-32 (wheat variety) as the test crop. Eight treatments were evaluated: T_0=Control (No chemical fertilizers), T_1=N_{140} P_{25} K_{110} S_{16} kg ha^{-1} (Recommended Fertilizer Dose), T_2=T_1+Zn and B application in soil @ Zinc 2 kg ha^{-1}, B 1 kg ha^{-1}, T_3=T_1+Zn and B once foliar application @ Zinc 2 kg ha^{-1}, B 1 kg ha^{-1} at 50 DAS, T_4=T_1+Zn and B twice foliar application @Zinc 2 kg ha^{-1}, B 1 kg ha^{-1} at 35 DAS and 50 DAS, T_5=T_1+Zn and B twice foliar application @ Zinc 1 kg ha^{-1}, B 0.5 kg ha^{-1} at 35 DAS and 50 DAS, T_6=T_1+Zn and B once foliar application @ Zinc 1 kg ha^{-1}, B 0.5 kg ha^{-1} at 35 DAS and T_7=T_1+Zn and B once foliar application @ Zinc 1 kg ha^{-1}, B 0.5 kg ha^{-1} at 50 DAS. Results indicated that T_4 significantly improved growth and yield attributes. Maximum plant height (79.46 cm), spike length (14.92 cm), flag leaf length (14.22 cm), total tillers plant^{-1} (5.33), spikelets spike^{-1} (15.86), grains spike^{-1} (45.53), 1000-seeds weight (56.00 g), grain yield (4.13 t ha^{-1}), straw yield (4.74 t ha^{-1}), and harvest index (46.52%) were recorded with T_4. Conversely, the control (T_0) showed the lowest results across all parameters.

KEYWORDS: Wheat, zinc, boron, growth, yield

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1. INTRODUCTION

Wheat (*Triticum aestivum* L.), known as the "King of cereals" (Hossain et al., 2024), is a crucial self-pollinated crop supporting about two-thirds of the world's population (Azad et al., 2022) by providing 20% of the food calories for approximately 55% of the global population (Majeed et al., 2024). It provides essential nutrients including energy, proteins, carbohydrates, and dietary calories (Poole et al., 2021). Wheat grains contain 78.10% starch, 14.70% protein, 2.14% fat, and 2.10% mineral matter (Kumar et al., 2011), including selenium and magnesium (Topping, 2007). It is the most important crop considered integral to the food security of many nations (Hossain et al., 2024). Globally, wheat was cultivated on 220.76 mha in 2021, yielding 770.87 mt, making it the second most-produced cereal after maize (Anonymous, 2022). Major producers include China, India, Russia, the United States, France, and Ukraine, contributing 56.6% of global wheat production (Anonymous, 2022).

Key challenges affecting wheat production include low-quality seed, salinity, waterlogging, lack of irrigation, high input costs, low farmer education, non-judicial fertilizer use, and insufficient micronutrients and organic fertilizers (Khan et al., 1996). Increasing micronutrient-deficient soils, driven by intensive farming and excessive fertilizer use, further exacerbate these issues (Salim, 2020; Ranjbar et al., 2007). Micronutrients are vital for increasing wheat yield, especially in regions like Bangladesh where soil deficiencies are common (Akter et al., 2019; Soleimani, 2006; Leiw, 1988).

Zinc is crucial for various physiological processes including fertilization, pollen formation, cell elongation, chlorophyll formation, protein synthesis, and enzymatic functions (Sattar et al., 2022). Zinc fertilization enhances wheat yield and zinc content in grain (Das et al., 2020), impacting nitrogen metabolism, photosynthesis, stress resistance, and biomass production (Cakmak, 2008). Zinc deficiencies are often due to low solubility rather than low total content in soils (Cakmak, 2008). Soil or foliar application of Zn plays a major role in plant defense mechanisms against biotic and abiotic stresses (Cabot et al., 2019) by improving antioxidant defense mechanisms (Sattar et al., 2022; Zarea and Karimi, 2023).

Boron is essential for nutrient absorption of N, P, K (Akter et al., 2019) and numerous plant functions including membrane stability, cell wall structure, (Brown et al., 2002), metabolism of carbohydrates, nucleic acids, IAA, and sugar transportation (Marschner, 1995). It is also important for pollen germination, flowering, seed development, and grain setting in wheat (Brown et al., 2002; Wang et al., 2003; Tahir et al., 2009). Boron deficiency leads to poor seed quality, male sterility, and increased disease susceptibility (Jahiruddin, 2011). Foliar application of boron at the booting stage improves grain size, number of grains, and yield of wheat (Ahmad et al., 2021; Fakir et al., 2016).

Foliar application of micronutrients is 6–20 times more efficient than soil application for improving plant nutrition (Dass et al., 2022; Torun et al., 2001). It mitigates soil factors that limit nutrient bioavailability by enabling rapid absorption and reducing losses from leaching and fixation. Studies show that foliar-applied zinc enhances wheat yield, its components, and grain quality (Bameri et al., 2012). Additionally, integrating soil and foliar applications can be as effective or superior to soil application alone, further optimizing nutrient use and improving crop productivity (Firdous et al., 2016). Foliar application of zinc and boron enhances plant growth and crop production, making it an important practice to study for increasing growth and yield attributes in wheat.

2. MATERIALS AND METHODS

2.1. Study sites

The research occurred from November, 2022–March, 2023 at Sher-e-Bangla Agricultural University (SAU) in Dhaka, Bangladesh. The experimental field, situated at 23°41'N latitude and 90°22'E longitude, sits 8.4 meters above sea level in the Madhupur Tract (AEZ-28). During the 2022 Rabi season, the experiment utilized typical wheat-growing soil classified as "Deep Red Brown Terrace Soil" of the Tejgaon Series. Above flood level, the site received ample sunlight throughout the study period.

2.2. Planting material

The experiment used the wheat variety BARI Gom-32, developed by the Bangladesh Agricultural Research Institute (BARI) and released in 2017. Suitable for planting until mid-December, this variety resists leaf rust and *Bipolaris* leaf blight, and produces 3–4 tillers plant^{-1}. It has wide, deep green leaves, amber grains, and a heading period of 60–63 days. The seeds of this variety were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur.

2.3. Treatments of the experiment

The study consisted of the following treatments:

T_0=Control (No chemical fertilizers)

T_1=N_{140} P_{25} K_{110} S_{16} kg ha^{-1} (Recommended Fertilizer Dose)

T_2=T_1+Zn and B application in soil @ Zinc 2 kg ha^{-1}, B 1 kg ha^{-1}

T_3=T_1+Zn and B once foliar application @ Zinc 2 kg ha^{-1}, B 1 kg ha^{-1} at 50 DAS

T_4=T_1+Zn and B twice foliar application @ Zinc 2 kg ha^{-1}, B 1 kg ha^{-1} at 35 DAS and 50 DAS

T_5=T_1+Zn and B twice foliar application @ Zinc 1 kg ha^{-1}, B 0.5 kg ha^{-1} at 35 DAS and 50 DAS

T_6=T_1+Zn and B once foliar application @ Zinc 1 kg ha^{-1}, B 0.5 kg ha^{-1} at 35 DAS

T_7=T_1+Zn and B once foliar application @ Zinc 1 kg ha^{-1}, B 0.5 kg ha^{-1} at 50 DAS

2.4. Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design with three replications per treatment. Each plot measured 2.5 m by 2 m, with 1 m between blocks and 0.75 m between rows. Footpaths and irrigation/drainage canals were included in the gaps between blocks and rows.

2.5. Fertilizer application and seed sowing

Fertilizer was applied according to the BARC fertilizer recommendation guide-2018. Urea, TSP, MoP and Gypsum were used as N, P, K, and S sources, respectively. All P, K, S, and half of N were applied at the last land preparation stage, and the remaining half of N was applied before booting.

On 15th November 2022, seeds were sown by hand. Healthy seeds of wheat @ 120 kg ha^{-1} were sown in line and then well covered with soil. The line-to-line distance for wheat was 20 cm and the plant-to-plant distance was 4–5 cm.

2.6. Methods of data collection

Crop sampling was done during harvest. The harvest date was 6th March, 2023. At each harvest, five plants were selected at random from each plot. The plants in each plot were carefully cut at the soil surface level. Data included growth parameters [plant height (cm), length of flag leaf (cm)], yield-contributing parameters [spike length (cm), number of spikelet $spike^{-1}$, total number of tillers, number of total grain $spike^{-1}$], and yield parameters [1000-grain weight (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), harvest index (%)].

2.7. Statistical analysis

The data of observation were analyzed using analysis of variance (ANOVA). The Statistics 10 computer program was employed for the statistical analysis of the data derived from the experiment's diverse parameters. Mean values for each parameter were computed, and an analysis of variance was conducted. To assess the significance of differences among treatment means, the Duncan Multiple Range Test was utilized at a 5% probability level.

3. RESULTS AND DISCUSSION

3.1. Plant height (cm)

Foliar treatment with various doses of Zn and B fertilizers, along with other chemical fertilizers, positively affected wheat plant height at harvest. The application of Zn and B significantly increased plant height compared to the control without these elements (Table 1). The T_4 treatment produced the tallest plants at 79.46 cm, significantly taller than other treatments, followed by T_6 at 74.02 cm, while the control (T_0) had the shortest plants at 63.01 cm. The increase in plant height might be attributed due to the zinc is an activator of plant nutrients and plays an important role in the growth and development of plants because of its stimulatory and catalytic effect in various physiological and metabolic processes of plants and boron is involved in the transportation of photosynthates from leaves to other plant parts which ultimately increased the plant height (Ma et al., 2017). The combined application of Zn and B increased plant height by activation of different physiological processes like stomatal regulation (Zain et al., 2015), chlorophyll formation, enzyme activation (Rashid et al., 2011), and biochemical processes (Alotaibi et al., 2023).

Table 1: Effect of foliar application of Zn and B on plant height (cm), length of flag leaf (cm), spike length (cm) and number of spikelet $spike^{-1}$ of wheat

Treatment	Plant height (cm)	Length of flag leaf (cm)	Spike length (cm)	No. of spikelet $spike^{-1}$
T_0	63.01^{d}	9.49^{e}	10.84^{d}	10.60^{d}
T_1	68.90^{c}	10.46^{de}	11.26^{cd}	11.92^{cd}
T_2	71.87^{bc}	11.64^{cd}	12.02^{bcd}	13.00^{bc}
T_3	72.64^{b}	12.88^{abc}	13.12^{b}	12.60^{bc}
T_4	79.46^{a}	14.22^{a}	14.92^{a}	15.86^{a}
T_5	73.84^{b}	13.52^{ab}	13.18^{b}	14.26^{ab}
T_6	74.02^{b}	11.85^{cd}	12.74^{bc}	12.56^{c}
T_7	73.82^{b}	12.39^{bc}	12.51^{bc}	12.53^{c}
CV%	2.60	7.38	6.87	7.53
LSD (p=0.05)	3.28	1.56	1.51	1.70

3.2. Length of flag leaf (cm)

Due to the foliar application of Zn and B, the length of the wheat flag leaf (cm) varied significantly (Table 1). Among all treatments, T_4 exhibited the maximum flag leaf length (14.22 cm), which was statistically identical to T_5 (13.52 cm) and T_3 (12.88 cm). In contrast, T_0 (control) had the shortest flag leaf length (9.49 cm), which was statistically identical to T_1 (10.46 cm). This increase could also be attributed to the enhanced length and width of leaves, as Zn is involved in cell division (Zhu et al., 2015). Zhou et al. (2016) concluded that plants treated with foliar application of Zn and B mixture produced more Leaf Area Index (LAI) which might be due to an increase in indole acetic acid hormone through B fertilization.

3.3. Spike length (cm)

Different Zn and B treatments applied to wheat showed significant effects on spike length (Table 1) which is another key growth characteristic of wheat. The treatment T_4 recorded the highest spike length (14.92 cm), which was significantly different from the others and the smallest spike length (10.84 cm) was observed in T_0 (control), which was statistically identical to T_1 (11.26 cm). Arshad et al. (2016) reported that Zn application had significantly increased wheat spike length (10.78 cm). This increase in spike length may also be possible owing to B spray as it is vital for the cell wall synthesis and also possesses a significant role in the growth and development of newly formed cells (Camacho-cristobal et al., 2008). Khan et al. (2019) stated that the combined effects of Zn and B have a considerable influence on spike length whereas Zn application might have increased the spike length because it helps to more availability of other nutrients.

3.4. Number of spikelet spike^{-1}

The foliar application of Zn and B resulted in statistically significant variation in the number of spikelets spike^{-1} of wheat (Table 1). The maximum number of spikelets spike^{-1} (15.86) was found from T_4 which was statistically similar to T_5 (14.26) treatments and the minimum number of spikelets spike^{-1} (10.60) was observed from T_0 (control) which was statistically similar to T_1 (11.92). The above results indicate that the number of spikelets spike^{-1} was enhanced by the interaction of Zn and B. It may be because zinc plays an important role in the formation of growth hormones and auxin metabolism, whereas boron is involved in the development of new cells in meristematic tissues and also regulates carbohydrate metabolism (Sharma et al., 2016).

3.5. Total number of tillers^{-1}

The foliar application of Zn and B gave rise to a statistically significant variation in the total tillers plant^{-1} in wheat (Table 2). Experiment results concluded that treatment T_4 generated the greatest number of total tillers plant^{-1} (5.33), which was significantly different from the other treatments, and T_0 (control) exhibited the fewest number of total tillers plant^{-1} (3.90), followed by T_2, T_1, and T_6 treatments. This increase in the total number of tiller plant^{-1} may be due to the sufficient availability of plant nutrients such as N, P, K, Zn, and B to wheat plants, possibly due to the synergistic effect of zinc and boron enhancing their contents and uptake. These results are comparable as per the report of Singh et al. (2015), and Sharma et al. (2017).

3.6. Number of total grain spike^{-1}

The total number of grain spikes^{-1} in wheat showed statistically significant variance as a result of the foliar application of Zn and B fertilizer (Table 2). Results showed that T_4 had the most total grains spike^{-1} (45.53), which was statistically different from other treatments. From T_0 (control), the smallest number of full grains spike^{-1} (27.60) was recorded. This may be attributed due to the Zinc plays a crucial role in regulating auxin concentration in plants, serving as an essential component of enzymes that promote plant growth and development, including the initiation of primordia for reproductive parts and Boron also plays a vital role in the translocation of photosynthates, increased pollination and grain setting in wheat and ultimately sterility is reduced and number of grains spike^{-1} increased. These results conform with those already reported by Ali et al. (2013), Cakmak et al. (2008), and Patel et al. (2008).

Table 2: Effect of foliar application of Zn and B on total number of tillers^{-1}, number of total grain spike^{-1} and 1000-grain weight (g) of wheat

Treatment	Total number of tillers^{-1}	Number of total grain spike^{-1}	1000-grain weight (g)
T_0	3.90^{e}	27.60^{e}	49.33^{d}
T_1	4.26^{cde}	31.46^{d}	50.66^{cd}
T_2	4.10^{de}	34.46^{cd}	51.66^{bc}
T_3	4.56^{bc}	34.66^{cd}	51.00^{bcd}
T_4	5.33^{a}	45.53^{a}	56.00^{a}
T_5	4.76^{b}	40.13^{b}	52.00^{bc}
T_6	4.26^{cde}	38.86^{b}	53.00^{b}
T_7	4.50^{bcd}	36.86^{bc}	51.33^{bcd}
CV%	5.16	5.34	2.36
LSD (p=0.05)	0.40	3.38	2.14

3.7. 1000-grain weight (g)

Significant variation was observed for 1000 grain weight of wheat caused by foliar application Zn and B (Table 2). Results showed that T_4 recorded the highest 1000-grain weight (56.00 g), significantly differing from other treatments. On the other hand, T_0 (control) had the lowest weight (49.33 g), statistically similar to T_2, T_7, T_3, and T_1. Ali et al. (2009) found that combined foliar application of both Zinc and Boron significantly increased 1000-grain weight and also reported that 1000-grain weight increased by 4.88% over control treatment. The findings conform with those already reported by Singh et al. (2015).

3.8. Grain yield (t ha^{-1})

The grain yield (t ha^{-1}) of wheat showed notable variation due to the foliar application of Zn and B (Table 3). Results signified that that the highest grain yield (4.13 t ha^{-1}) was found from the treatment T_4 which was significantly different from all other treatments and the lowest grain yield (2.67 t ha^{-1}) was obtained from the control treatment T_0 (control). The previous study by Sharma et al. (2016) is in agreement with the findings of this study and indicated that foliar application of Zn and B improved dry matter and grain yield due to improvement in allometric traits, chlorophyll and relative water contents, and increase in yield components. The combined foliar application of Zn and B with N, P, K and S gave the highest 1000 grain weight (54.84 g), grain yield (4.25 t ha^{-1}), Stover yield (4.96 t ha^{-1}) and harvest index (46.15%) (Hossain et al., 2024).

3.9. Straw yield (t ha^{-1})

Significant differences due to the foliar application of Zn and B were observed in the straw yield of wheat (Table 3). The highest straw yield (4.74 t ha^{-1}) was found from T_4 which was statistically different from others. The lowest straw yield (3.72 t ha^{-1}) was obtained from T_1 which was statistically identical to T_0 (3.96 t ha^{-1}). It is attributed due to the sufficient availability of plant nutrients as like N, P, K, Zn, and B to wheat plant up to harvest the of crop, which mainly increases the biomass production of plants. The findings of this study are in accordance with Sharma et al. (2017) and Kapoor et al. (2016).

Table 3: Effect of foliar application of Zn and B on grain yield (t ha^{-1}), straw yield (t ha^{-1}) and harvest index (%) of wheat

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
T_0	2.67^{g}	3.96^{de}	40.31^{f}
T_1	2.80^{fg}	3.72^{e}	42.97^{de}
T_2	3.06^{e}	4.16^{cd}	42.40^{de}
T_3	3.89^{f}	4.05^{d}	41.69^{e}
T_4	4.13^{a}	4.74^{a}	46.52^{a}
T_5	3.95^{b}	4.70^{a}	45.68^{ab}
T_6	3.61^{c}	4.51^{ab}	44.46^{bc}
T_7	3.35^{d}	4.41^{bc}	43.17^{cd}
CV%	2.35	3.75	1.79
LSD(p=0.05)	0.13	0.28	1.36

3.10. Harvest index (%)

The foliar application of Zn and B resulted in significant variations in terms of the harvest index of wheat (Table 3). The highest harvest index (46.52%) was recorded from T_4 and the lowest harvest index (40.31%) was observed from T_0 (control). Foliar application of Zn and B increased the biological yield and harvest index, might be to owing increased chlorophyll contents and grain yield (Kumar et al., 2019). It might be because of the activation of different physiological processes like stomatal regulation, chlorophyll formation, enzyme activation and biochemical processes through the application of micronutrients (Cakmak, 2008) which resulted in high dry matter and yield.

4. CONCLUSION

Foliar application of Zn and B significantly enhanced growth and yield attributes of wheat, with the T_4 treatment (T_1+Zn and B twice foliar application @ Zinc 2 kg ha^{-1}, B 1 kg ha^{-1} at 35 DAS and 50 DAS) showing the best results. Despite these positive outcomes, further research in different Agro-Ecological Zones (AEZs) of Bangladesh is recommended to validate these findings and develop comprehensive recommendations for wheat cultivation across the country.

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