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Effect of Zinc and Boron Application on Growth, Yield, Nutrient Uptake and Residual Soil Fertility in Wheat (*Triticum aestivum* L.)

Pradeep Kumar*, A S Rajput and P D Verma
Krishi Vigyan Kendra Bhatapara, 493118, (Chhattisgarh), India

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ABSTRACT

Micronutrient management plays a crucial role in enhancing wheat productivity and soil fertility. This study was conducted to evaluate the effects of zinc (Zn) and boron (B) application on wheat growth, yield, nutrient uptake, and post-harvest soil fertility. The experiment included different Zn and B application methods, with a focus on foliar and soil applications. Among the treatments, the combined foliar application of Zn (0.5%) and B (0.2%) recorded the highest plant height, advanced flowering (67.4 d), and earliest physiological maturity (112.63 d), indicating improved vegetative growth and crop development. The highest grain (44.57 q/ha) and straw yield (58.4 q/ha) were observed in foliar application of Zn (0.5%) and B (0.2%), followed by soil application of Zn (25 kg/ha) and B (2 kg/ha). Enhanced nutrient uptake in foliar application of Zn (0.5%) and B (0.2%) resulted in the highest Zn (38.27 mg/kg in grain, 26.47 mg/kg in straw) and B (8.30 mg/kg in grain, 5.33 mg/kg in straw) concentrations. Post-harvest soil analysis revealed that residual Zn (1.47 mg/kg) and B (1.08 mg/kg) were highest in soil application of Zn (25 kg/ha) and B (2 kg/ha), suggesting a stronger residual effect through soil application. Correlation analysis confirmed a significant positive relationship between Zn and B uptake and yield components, emphasizing their essential role in wheat productivity. The results suggest that an integrated Zn and B fertilization strategy, particularly combining soil and foliar applications, can enhance wheat growth, improve yield, and sustain soil fertility. These findings provide valuable insights for optimizing micronutrient management in wheat cultivation to ensure long-term productivity and soil health.

Keywords: Boron, Foliar application, Management, Micronutrient, Nutrient Uptake, Soil Fertility, Wheat, Zinc

INTRODUCTION

Wheat (*Triticum aestivum L.*) is a staple food crop, contributing significantly to global food security and nutrition (Sharma and Singh, 2020). In India, wheat occupies a pivotal position in the agricultural economy, with millions of farmers dependent on its cultivation for their livelihood (Kaur *et al,* 2020). With the growing demands of an increasing population, modern agriculture has become more intensive, depleting soil nutrients over time (Kumar, 2013). One of the key drivers behind the remarkable increase in wheat production and yield has been the use of synthetic fertilizers, particularly nitrogen (Chourasiya *et al*, 2022). Along with nitrogen, phosphorus and potassium fertilizers have played a crucial role in supporting wheat growth, development, and productivity. Beyond these primary macronutrients, wheat also requires several micronutrients in small quantities, which are essential for optimal growth. Among these, boron (B), zinc (Zn), iron (Fe), copper (Cu), manganese (Mn), and chlorine (Cl) significantly influence both grain and straw yield. Although required in trace amounts, these micronutrients are vital for improving nutrient uptake and enhancing physiological processes that ultimately contribute to higher yields (Rehm and Sims, 2006). Their adequate supply ensures better nutrient availability, supporting key cellular functions such as photosynthesis, respiration, chlorophyll formation, nucleic acid and protein synthesis, nitrogen fixation, and other biochemical pathways (Taiwo *et al,* 2001). Consequently, maintaining balanced micronutrient levels is critical for sustaining wheat productivity and soil health. However, achieving higher productivity and quality in wheat is often constrained by nutrient deficiencies in the soil, particularly micronutrients such as zinc (Zn) and boron (B). According to Alloway (2008), zinc deficiency is one of the most widespread micronutrient deficiencies in cereal crops worldwide, affecting nearly 50% of Indian soils (Shukla *et al,* 2015). Similarly, boron deficiency is prevalent in more than 30% of cultivated soils in India, causing reduced

Corresponding Author's Email - kashyappradeep42@gmail.com

Table 1: Initial Soil Physico-chemical properties of the experimental site

Soil Property	Value	Method Used
pH (1:2.5 soil-water suspension)	7.6	Jackson (1973)
EC (dS/m at 25°C)	0.12	Jackson (1973)
Organic Carbon (%)	0.52	Walkley & Black Method
Available Nitrogen (kg/ha)	238	Alkaline $KMnO_4$ Method
Available Phosphorus (kg/ha)	18.4	Olsen's Method
Available Potassium (kg/ha)	290	Flame Photometer (NH_4OAc extractable)
DTPA-extractable Zinc (mg/kg)	0.46	DTPA Extraction Method (Lindsay & Norvell, 1978)
Hot Water-Soluble Boron (mg/kg)	0.28	Berger & Truog Method

Table 2: Effect of zinc and boron on plant height (cm) in different growth stages of wheat

Treatment	30 DAS	60 DAS	90 DAS
T1 (Control)	18.36	46.4	81.33
T2 (NPK)	22.46	52.56	89.47
T3 (NPK + Zn @ 25 kg/ha)	23.56	56.33	94.23
T4 (NPK + B @ 2 kg/ha)	24.33	55.56	93.23
T5 (NPK + Zn @ 25 kg/ha + B @ 2 kg/ha)	25.46	58.56	97.50
T6 (NPK + Foliar Zn @ 0.5% + B @ 0.2%)	26.3	60.3	99.30
CD	3.67	7.09	9.73
SE(m)	1.15	2.22	3.05

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grain filling, poor root development, and stunted plant growth (Rashid *et al,* 2002).

Zinc is essential for numerous enzymatic processes, protein synthesis, and hormonal regulation in plants. It plays a crucial role in enhancing photosynthesis and improving grain quality through better protein and carbohydrate synthesis (Cakmak, 2000). It improves the number of grains per spike (Asad and Rafique, 2002). In addition to the yield, adequate supply of Zn can improve the water use efficiency of wheat plants (Bagci *et al,* 2007). It also provides thermo-tolerance to the photosynthetic apparatus (Graham and McDonald, 2001). It is important in plant metabolism and thus the growth and production of wheat (Genc *et al,* 2006). Zinc deficiency in plants not only reduces the grain yield, but also the nutritional quality of crops (Erenoglu *et al,* 1999). Boron is vital for cell wall formation, pollen viability, and reproductive growth, particularly in cereals (Goldbach *et al,* 2001). However, the deficiency of B is the most frequently encountered in field (Gupta and Mehla, 1993). Boron is essential for cell division and elongation of meristematic tissues, floral organs and the flower male fertility, pollen tube germination and its elongation and the seed and fruit formation. Lack of B can cause 'wheat sterility' resulting in increased number of open spikelets and decreased number of grains per spike (Rerkasem *et al,* 2004). The B deficiency in soil can affect seedling emergence and cause an abnormal cellular development in young wheat plant (Snowball and Robson, 1983). It also inhibits root elongation by limiting cell division in the growing zone of root tips (Dell and Huang, 1997).

Continuous cropping, imbalanced fertilizer use, and low organic matter content in soils have exacerbated the depletion of zinc and boron in Indian soils. Despite the use of recommended doses of macronutrients (NPK), the lack of adequate attention to micronutrient supplementation has led to declining crop productivity over the years. This highlights the need for incorporating micronutrient-based fertilizers into current nutrient management practices. Zinc and boron deficiencies pose a significant challenge to sustainable wheat production in zinc- and boron-deficient soils. Although studies have demonstrated the benefits of micronutrient application in enhancing yield and nutrient use efficiency (Choudhary et al., 2020), region-specific data and field-level validation are limited, particularly in Balodabazar district. Addressing this gap is essential to improving soil fertility and ensuring food security for resource-limited farmers. The study aims to evaluate the effects of zinc and boron application on wheat growth, yield, and quality. It also seeks to assess the changes in soil

Table 3: Effect of zinc and boron on days to 50% flowering and physiological maturity of wheat

Treatment	Days to 50% flowering	Days to physiological maturity
T1 (Control)	74.3	119.33
T2 (NPK)	71.5	116.50
T3 (NPK + Zn @ 25 kg/ha)	70.5	115.67
T4 (NPK + B @ 2 kg/ha)	70.4	114.53
T5 (NPK + Zn @ 25 kg/ha + B @ 2 kg/ha)	68.8	113.40
T6 (NPK + Foliar Zn @ 0.5% + B @ 0.2%)	67.4	112.63
CD	N/A	N/A
SE(m)	1.31	2.89

Table 4: Effect of zinc and boron on grain yield, straw yield and harvest index of wheat

Treatment	Grain Yield (q/ha)	Straw Yield (q/ha)	Harvest Index (%)
T1 (Control)	30.40	42.4	41.767
T2 (NPK)	34.57	49.3	41.233
T3 (NPK + Zn @ 25 kg/ha)	38.53	52.467	42.367
T4 (NPK + B @ 2 kg/ha)	38.33	52.433	42.233
T5 (NPK + Zn @ 25 kg/ha + B @ 2 kg/ha)	42.30	56.267	42.9
T6 (NPK + Foliar Zn @ 0.5% + B @ 0.2%)	44.57	58.4	43.3
CD	4.03	5.15	N/A
SE(m)	1.26	1.614	1.034

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micronutrient status and recommend appropriate micronutrient management strategies for wheat cultivation in Balodabazar district.

MATERIALS AND METHODS

The study was conducted in district Chhattisgarh. The soil type in this region primarily consisted of Vertisols and Inceptisols, which were characterized by low zinc and boron availability. The district experienced a tropical monsoon climate with an average temperature ranging from 15°C to 35°C during the wheat-growing season (*Rabi*). The annual rainfall was approximately 1,200 mm, but wheat was cultivated under irrigated conditions. The experiment was laid out in a Randomized Block Design (RBD) with three replications. The study utilized a high-yielding wheat variety such as CG Gehu-4, which was commonly grown in the region. Six treatments were tested in the experiment. The control (T1) involved no application of zinc or boron, while another treatment consisted of T2: NPK, T3: NPK + Zinc @ 25 kg $ZnSO_4$/ha as basal soil application, T4: NPK + Boron @ 2 kg Borax/ha as basal soil application, T5: NPK + Zn @ 25 kg $ZnSO_4$/ha + B @ 2 kg Borax/ha as basal soil application and T6: NPK + Zn @ 0.5% + B @ 0.2% as foliar spray at 30 & 45 DAS. The recommended dose of NPK (120:60:40 kg/ha) was applied uniformly across all plots using urea, DAP, and MOP fertilizers. The micronutrients zinc and boron were applied as per the respective treatment allocations, either as a basal soil application or through foliar spraying at critical growth stages. The crop was sown using a seed drill, ensuring a seeding depth of 5 cm, with a seed rate of 100 kg/ha. Irrigation was provided at five critical stages: Crown Root Initiation (CRI), tillering, booting, flowering, and grain filling. Weed management was carried out using a post-emergence herbicide, Clodinafop-propargyl 15% + Metsulfuron Methyl 1% at 30 DAS.

Agronomic observations included plant height measurements at 30, 60, and 90 DAS, number of tillers per plant at 45 and 90 DAS, and days to 50% flowering and physiological maturity. Yield parameters were assessed by measuring grain yield, straw yield, and harvest index to evaluate overall productivity. Nutrient analysis was conducted to determine zinc and boron concentrations in grain and straw samples, using Atomic Absorption Spectroscopy (AAS). Nutrient uptake was calculated by multiplying the grain and straw yield with their respective nutrient concentrations. Soil analysis was conducted both before sowing and after harvest. Initial soil properties, including available zinc (DTPA-extractable) and boron (hot water-soluble), along with pH, electrical conductivity (EC), and organic carbon percentage, were measured. Post-harvest soil samples were analysed for changes in zinc and boron availability to

Table 5: Zinc and Boron Concentrations in Grain and Straw as influenced by zinc and boron application in wheat

Treatment	Zinc in Grain (mg/kg)	Zinc in Straw (mg/kg)	Boron in Grain (mg/kg)	Boron in Straw (mg/kg)
T1 (Control)	20.27	14.40	5.17	3.30
T2 (NPK)	25.43	16.57	5.50	3.43
T3 (NPK + Zn @ 25 kg/ha)	32.43	22.43	6.33	3.47
T4 (NPK + B @ 2 kg/ha)	26.60	17.50	7.40	4.37
T5 (NPK + Zn @ 25 kg/ha + B @ 2 kg/ha)	35.37	24.43	7.57	4.53
T6 (NPK + Foliar Zn @ 0.5% + B @ 0.2%)	38.27	26.47	8.30	5.33
CD	4.00	4.09	1.94	N/A
SE(m)	1.25	1.28	0.61	0.51

Table 6: Zinc and Boron uptake by Grain and Straw as influenced by zinc and boron application in wheat

Treatment	Zinc in Grain (g/ha)	Zinc in Straw (g/ha)	Boron in Grain (g/ha)	Boron in Straw (g/ha)
T1 (Control)	61.73	61.17	21.60	10.167
T2 (NPK)	88.20	82.03	22.77	11.933
T3 (NPK + Zn @ 25 kg/ha)	125.23	117.93	26.90	13.5
T4 (NPK + B @ 2 kg/ha)	102.23	91.43	31.20	16.833
T5 (NPK + Zn @ 25 kg/ha + B @ 2 kg/ha)	149.87	137.10	32.47	19.3
T6 (NPK + Foliar Zn @ 0.5% + B @ 0.2%)	170.80	154.13	35.93	23.867
CD	27.35	20.31	8.83	7.917
SE(m)	8.57	6.36	2.76	2.48

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assess the residual effects of micronutrient application. Statistical analysis was performed using ANOVA (Analysis of Variance) to determine significant differences among treatments. Means were compared using Least Significant Difference (LSD) at $p < 0.05$, ensuring statistical reliability of results.

RESULTS AND DISCUSSION

Plant height (cm)

The effect of zinc and boron application on plant height at different growth stages of wheat was evaluated, and the results are presented in Table 2. A significant increase in plant height was observed with the application of NPK alone (T2) compared to the control (T1) across all growth stages. At 30 DAS, plant height increased from 18.36 cm in the control to 22.46 cm with NPK application. Further improvement was recorded with the addition of zinc (T3) and boron (T4), wherein plant height reached 23.56 cm and 24.33 cm, respectively. The combined application of Zn and B (T5) resulted in a further increase to 25.46 cm, while foliar application of Zn and B (T6) recorded the maximum plant height of 26.3 cm at this stage. A similar trend was observed at 60 DAS and 90 DAS, where the control recorded the lowest plant height, and the application of NPK significantly enhanced growth. The addition of Zn and B further improved plant height, with foliar application (T6) consistently showing the highest values at both stages. At 90 DAS, the maximum plant height (99.30 cm) was recorded in T6, followed by T5 (97.50 cm), while the control (T1) had the lowest height (81.33 cm). The data indicated that the differences among treatments were statistically significant.

The results suggested that the application of Zn and B, either through soil or foliar application, plays a crucial role in enhancing wheat growth. The foliar application of Zn (0.5%) and B (0.2%) proved to be the most effective, indicating the potential for improved nutrient use efficiency and plant

Table 7: Post-Harvest Soil Zinc and Boron Availability as Influenced by Zinc and Boron Application in Wheat

Treatment	Available Zinc (mg/kg)	Available Boron (mg/kg)
T1 (Control)	0.52	0.38
T2 (NPK)	0.67	0.45
T3 (NPK + Zn @ 25 kg/ha)	1.24	0.49
T4 (NPK + B @ 2 kg/ha)	0.75	0.83
T5 (NPK + Zn @ 25 kg/ha + B @ 2 kg/ha)	1.47	1.08
T6 (NPK + Foliar Zn @ 0.5% + B @ 0.2%)	1.38	0.94
CD	0.16	0.12
SE(m)	0.05	0.04

Table 8: Correlation between (Zn, B) uptake and grain and straw yield of wheat

Parameter	Zn Uptake (Grain)	Zn Uptake (Straw)	B Uptake (Grain)	B Uptake (Straw)	Grain Yield	Straw Yield
Zn Uptake (Grain)	1.00	0.92**	0.75*	0.68*	0.89**	0.85**
Zn Uptake (Straw)	0.92**	1.00	0.70*	0.72*	0.87**	0.90**
B Uptake (Grain)	0.75*	0.70*	1.00	0.86**	0.82**	0.78**
B Uptake (Straw)	0.68*	0.72*	0.86**	1.00	0.79**	0.82**
Grain Yield	0.89**	0.87**	0.82**	0.79**	1.00	0.94**
Straw Yield	0.85**	0.90**	0.78**	0.82**	0.94**	1.00

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development. These findings highlight the importance of micronutrient management in wheat cultivation for optimizing growth and productivity. These findings align with the study by Ziaeyana and Rajaiea (2009), who observed that the combined application of Zn and B, especially through foliar methods, led to the most significant improvements in plant height across different growth stages

Days to 50% flowering and physiological maturity

The application of zinc and boron significantly influenced the phenological stages of wheat, as indicated by days to 50% flowering and physiological maturity (Table 3). The control treatment (T1) exhibited the longest duration to 50% flowering (74.3 days) and physiological maturity (119.33 days), suggesting that the absence of micronutrient supplementation delayed crop development. The application of NPK alone (T2) reduced the time to 50% flowering to 71.5 days and physiological maturity to 116.50 days, highlighting the role of balanced macronutrient nutrition in accelerating wheat growth. Further reductions were observed with the application of zinc (T3) and boron (T4), where days to 50% flowering decreased to 70.5 and 70.4 days, respectively, and physiological maturity was reached earlier (115.67 and 114.53 days, respectively). The combined application of Zn and B (T5) further shortened the growth duration, with the lowest values recorded in T6 (foliar application of Zn and B), where wheat reached 50% flowering in 67.4 days and physiological maturity in 112.63 days. This indicates that Zn and B supplementation not only enhances plant growth but also improves nutrient uptake efficiency, thereby reducing the time required to reach key phenological stages.

These findings align with recent studies highlighting the role of micronutrients in improving wheat growth and development. Research by demonstrated that zinc and boron application significantly reduced the number of days to flowering and maturity due to improved enzymatic activity and hormonal regulation in plant. Similarly, Kumar *et al* (2019) reported that the combined application of Zn and B led to earlier flowering and maturity in wheat, likely due to enhanced nitrogen metabolism and improved photosynthetic efficiency. Overall, the results of the present study suggest that the strategic use of Zn and B, particularly through foliar application, can effectively optimize wheat phenology, potentially

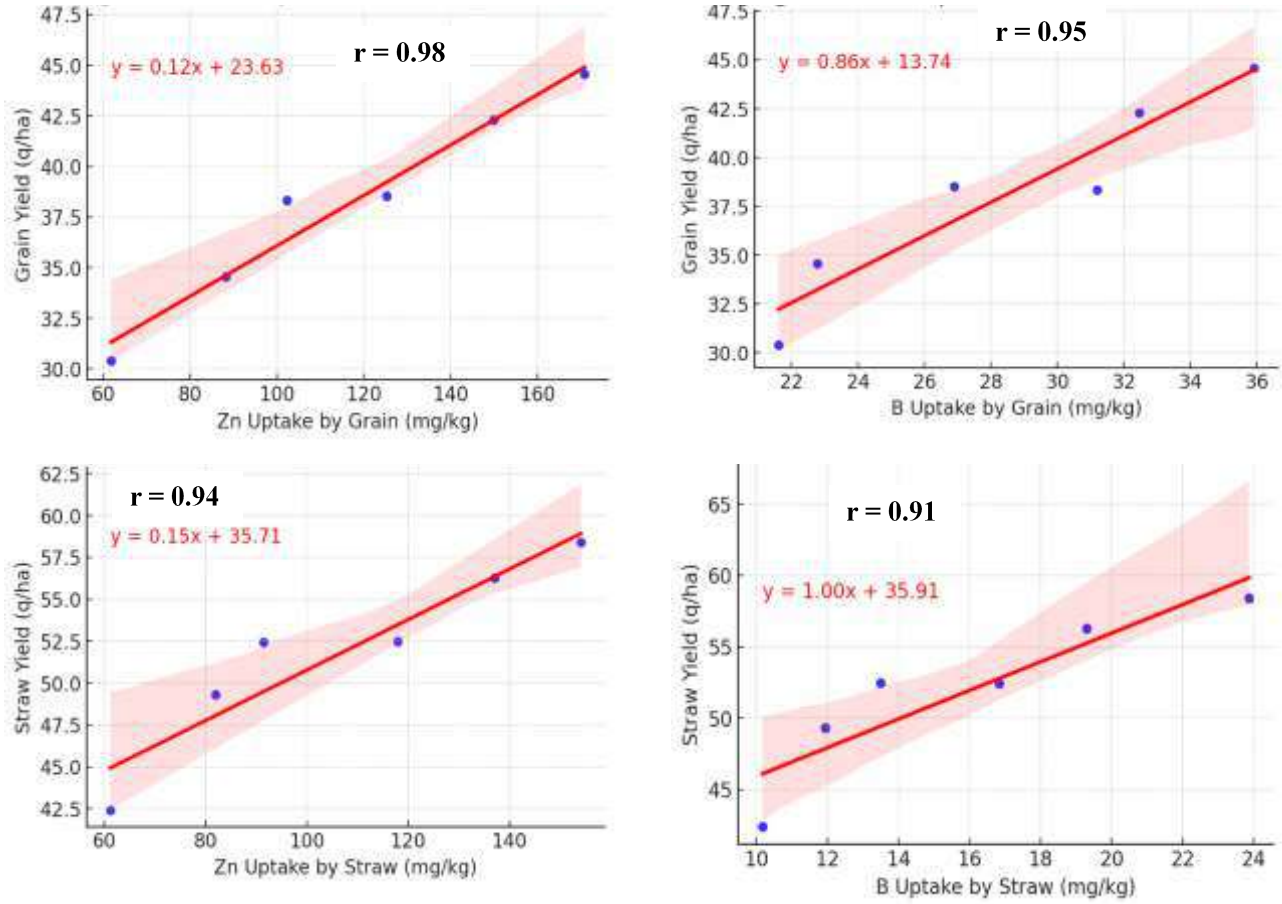


Fig. 1: Correlation coefficient (*r*) between the micronutrient (B, and Zn) uptake and the grain and straw yield of wheat

(**) Highly significant correlation ($p < 0.01$), (*) Significant correlation ($p < 0.05$)

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contributing to better yield formation and resource use efficiency.

Grain yield, straw yield and harvest index

The application of zinc and boron significantly influenced the grain yield, straw yield, and harvest index of wheat (Table 4). The lowest grain yield (30.40 q/ ha) and straw yield (42.4 q/ha) was found in control (T1), indicating suboptimal crop performance due to the lack of additional nutrient inputs. The application of NPK alone (T2) resulted in a higher grain yield (34.57 q/ha) and straw yield (49.3 q/ha), demonstrating the fundamental role of macronutrients in supporting wheat productivity. However, the inclusion of Zn (T3) and B (T4) further improved both grain and straw yields, with a notable increase observed in T3 (38.53 q/ ha grain yield and 52.467 q/ ha straw yield) and T4 (38.33 q/ ha grain yield and 52.433 q/ ha straw yield). The highest yields were recorded when both Zn and B were applied together. The combined soil application (T5) resulted in a grain yield of 42.30 q/ ha and straw yield of 56.267 q/ ha, while foliar application (T6) further enhanced grain yield to 44.57 q/ ha and straw yield to 58.4 q/ ha. The harvest index, which represents the proportion of economic yield to total biomass, was highest in T6 (43.3%), followed by T5 (42.9%), indicating improved partitioning of assimilates toward grain formation. The statistical analysis revealed significant improvement in grain and straw yield due to application of Zn and B.

These results are consistent with recent studies emphasizing the role of Zn and B in enhancing wheat productivity. Biswas and Biswas (2015) reported that the combined application of Zn and B improved grain yield by enhancing nutrient uptake, chlorophyll content, and enzymatic activities, leading to better grain filling. Similarly, Chaudhry *et al* (2007) demonstrated that Zn and B application significantly increased wheat yield attributes, as these micronutrients play a crucial role in enzyme activation, protein synthesis, and reproductive development. The findings of this study suggest that foliar application of

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Zn and B (T6) is the most effective strategy for enhancing wheat yield, likely due to improved nutrient availability and uptake efficiency. These results highlight the importance of integrating Zn and B fertilization in wheat production systems to optimize yield potential and resource utilization.

Zinc and boron concentrations in wheat grain and straw

The concentration of zinc and boron in wheat grain and straw varied significantly across treatments, indicating the influence of different fertilization strategies (Table 5). The lowest Zn and B concentrations were observed in the control (T1), where Zn content in grain and straw was 20.27 mg/kg and 14.40 mg/kg, respectively, while B content was 5.17 mg/kg in grain and 3.30 mg/kg in straw. The application of NPK alone (T2) improved these values slightly, with Zn concentrations increasing to 25.43 mg/kg in grain and 16.57 mg/kg in straw, and B concentrations rising to 5.50 mg/kg in grain and 3.43 mg/kg in straw. A substantial increase in Zn concentration was noted when Zn was applied at 25 kg/ha (T3), with values reaching 32.43 mg/kg in grain and 22.43 mg/kg in straw. Similarly, B application at 2 kg/ha (T4) significantly improved B concentration, reaching 7.40 mg/kg in grain and 4.37 mg/kg in straw. The combined soil application of Zn and B (T5) resulted in further enhancement, with Zn concentrations of 35.37 mg/kg in grain and 24.43 mg/kg in straw, while B concentrations reached 7.57 mg/kg in grain and 4.53 mg/kg in straw.

The highest Zn and B concentrations were recorded in T6, where foliar application of Zn (0.5%) and B (0.2%) led to Zn concentrations of 38.27 mg/kg in grain and 26.47 mg/kg in straw, and B concentrations of 8.30 mg/kg in grain and 5.33 mg/kg in straw. The critical difference (CD) values indicated that differences in Zn concentration were statistically significant, while variations in B concentration in straw were not statistically significant. These findings align with previous studies, where foliar Zn and B applications were found to enhance micronutrient concentration in wheat grains, thereby improving grain quality and nutrient bioavailability (Ziaeyana and Rajaiea, 2009).

Zinc and boron uptake (g/ha) by grain and straw in wheat

The uptake of zinc and boron in wheat grain and straw was significantly influenced by different fertilization treatments (Table 6). The lowest Zn and B uptake values were recorded in the control (T1), where Zn uptake was 61.73 mg/kg in grain and 61.17 mg/kg in straw, while B uptake was 21.60 mg/kg in grain and 10.167 mg/kg in straw. The application of NPK alone (T2) resulted in increased uptake, with Zn uptake rising to 88.20 mg/kg in grain and 82.03 mg/kg in straw, and B uptake increasing to 22.77 mg/kg in grain and 11.933 mg/kg in straw. Among the micronutrient treatments, the highest Zn uptake was recorded in T6 (foliar Zn and B application), with values of 170.80 mg/kg in grain and 154.13 mg/kg in straw. Similarly, B uptake was also highest in T6, with values of 35.93 mg/kg in grain and 23.867 mg/kg in straw. The combined soil application of Zn and B (T5) also resulted in significantly higher Zn and B uptake (149.87 mg/kg in grain and 137.10 mg/kg in straw for Zn, and 32.47 mg/kg in grain and 19.3 mg/kg in straw for B) compared to their individual applications (T3 and T4). The statistical analysis indicated that variations in Zn and B uptake across treatments were significant, as reflected by the critical difference (CD) values.

These results highlight the effectiveness of Zn and B fertilization, particularly through foliar application, in enhancing micronutrient uptake and accumulation in wheat plants. These findings are in agreement with previous studies, which demonstrated that Zn and B fertilization enhances nutrient uptake efficiency and improves wheat grain quality (Biswas and Biswas, 2015). The results suggest that integrated Zn and B management, especially through foliar application, can optimize micronutrient uptake, thereby improving crop productivity and nutritional quality.

Residual status of Zn and B (mg/kg) after harvest of wheat

The data suggest that the residual availability of zinc and boron in post-harvest soil was significantly influenced by the application of these micronutrients. The lowest residual Zn and B levels were recorded in the control (T1), with 0.52 mg/kg of Zn and 0.38 mg/kg of B, indicating depletion of soil micronutrients without external supplementation. The application of NPK alone (T2) improved the residual Zn (0.67 mg/kg) and B (0.45 mg/kg), but these values remained relatively low. Soil application of Zn at 25 kg/ha (T3) significantly increased residual Zn availability to 1.24 mg/kg, while B application at 2 kg/ha (T4) enhanced residual B to 0.83 mg/kg. The highest post-harvest availability of Zn (1.47 mg/kg) and B (1.08 mg/kg) was observed in T5 (NPK + Zn @ 25 kg/ha + B @ 2 kg/ha), indicating a stronger residual effect due to a well-balanced soil application of these micronutrients.

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Foliar application of Zn and B (T6) also improved residual Zn (1.38 mg/kg) and B (0.94 mg/kg), but the residual effect was slightly lower compared to soil application (T5). The significant differences suggest that soil application of Zn and B together had the most pronounced effect on post-harvest soil fertility, benefiting the succeeding crop by maintaining higher micronutrient availability. These results are aligned with the findings of Chanchal *et al* 2020.

Correlation between Zn and B uptake vs. grain and straw yield

A strong positive correlation was observed between Zn uptake by grain ($r = 0.89$, $p < 0.01$) and grain yield, indicating that higher Zn accumulation in grain is associated with increased wheat productivity. Similarly, Zn uptake by straw ($r = 0.90$, $p < 0.01$) showed a strong correlation with straw yield, emphasizing the role of Zn in overall biomass production. B uptake by grain ($r = 0.82$, $p < 0.01$) and straw ($r = 0.79$, $p < 0.01$) also exhibited significant positive relationships with grain and straw yield, confirming the importance of B in plant growth and yield improvement.

Interrelationship between Zn and B uptake

Zn uptake in grain and straw showed a strong correlation ($r = 0.92$, $p < 0.01$), suggesting that Zn availability in soil contributes to higher Zn accumulation in both plant parts. B uptake in grain was significantly correlated with B uptake in straw ($r = 0.86$, $p < 0.01$), indicating effective translocation of boron within the plant. A moderate positive correlation was observed between Zn and B uptake, suggesting that their availability may have a synergistic effect on plant nutrient absorption.

Grain vs. straw yield correlation

A highly significant positive correlation was observed between grain and straw yield ($r = 0.94$, $p < 0.01$), highlighting that improved plant nutrition leads to higher biomass production. The correlation analysis suggests that Zn and B uptake play a crucial role in enhancing wheat yield. The strong relationship between Zn and B uptake with both grain and straw yield indicates that balanced micronutrient management can improve overall crop productivity. Soil and foliar applications of Zn and B positively influence nutrient uptake, which translates into better growth, higher biomass accumulation, and increased grain yield. These findings emphasize the importance of integrated Zn and B fertilization strategies to optimize wheat production and ensure long-term soil fertility.

CONCLUSION

The present study demonstrated the significant impact of zinc (Zn) and boron (B) application on wheat growth, yield, nutrient uptake, and post-harvest soil fertility. The application of Zn and B, either individually or in combination, enhanced plant height, advanced flowering and physiological maturity, and improved grain and straw yield compared to the control and NPK-alone treatments. Among the different treatments, T6 (NPK + Foliar Zn @ 0.5% + B @ 0.2%) recorded the highest plant height at all growth stages, indicating improved vegetative growth due to the combined foliar application of Zn and B. The application of Zn and B significantly reduced the number of days required for 50% flowering and physiological maturity, with T6 showing the earliest flowering (67.4 d) and physiological maturity (112.63d), demonstrating the positive influence of micronutrient supplementation in accelerating crop growth. Grain and straw yield were significantly influenced by Zn and B application. The correlation analysis further confirmed that Zn and B uptake by grain and straw were positively correlated with grain and straw yield, highlighting their essential role in enhancing wheat productivity. The strong association between Zn and B uptake suggested that an integrated approach to micronutrient management is essential for sustainable wheat production. Overall, the results indicate that the combined application of Zn and B, particularly through soil application (T5) and foliar spray (T6), significantly enhances wheat growth, yield, nutrient uptake, and soil fertility. The findings suggest that balanced Zn and B fertilization should be integrated into nutrient management strategies to sustain wheat productivity and maintain soil health in the long run.

REFERENCES

Alloway B J (2008). Zinc in Soils and Crop Nutrition. International Zinc Association. pp. 1-135.

Bagci S A, Ekiz H, Yilmaz A and Cakmak I (2007). Effect of zinc deficiency and drought on grain yield of field-grown wheat cultivars in Central Anatolia. *J Agro Crop Sci* **193**: 198-206.

Biswas A and Biswas A (2015). Effect of Soil Zinc and Boron on the Yield and Uptake of Wheat in an Acid Soil of West Bengal, India. *Int J Plant Soil Sci* **6**(4): 203-217.

Cakmak I (2000). Possible roles of zinc in protecting plant cells from damage by reactive oxygen species. *New Phyto* **146**(2): 185-205.

Chanchal A, Singh S K, Patra A and Jatav S S (2020). Direct and Residual Effect of Boron Application on Yield and Nutrients Content under Rice–wheat Cropping System. *Curr J App Sci Tech* **39**(2): 12-22.

Chaudhry E H, Timmer V Javed A S and Siddique M T (2007). Wheat response to micronutrients in rain-fed areas of Punjab. *Soil Env* **26**: 97-101.

Choudhary M, Pandey R and Singh H (2020). Role of Zinc and Boron in Cereal Production. *Agriculture Reviews*.

Chourasiya A, Tripathi U K and Sharma A K (2022). Evaluation of frontline demonstration of zero tillage technology in wheat under semi-irrigated conditions. *J Krishi Vigyan* **10**(2): 146-149.

Dell B and Huang L B (1997). Physiological response of plants to low boron. *Plant and Soil* **193**: 103-120.

Erenoglu B, Cakmak I, Romheld V, Derici R and Rengel Z (1999). Uptake of zinc by rye, bread wheat and durum wheat cultivars differing in zinc efficiency. *Plant and Soil* **209**: 245-252.

Genc Y, McDonald G K and Graham R D (2006). Contribution of different mechanisms to zinc efficiency in bread wheat during early vegetative stage. *Plant and Soil* **281**: 353–367.

Goldbach H E, Huang L B and Wimmer M A (2001). Boron Functions in Plants and Animals: Recent Advances in Boron Research and Open Questions. In: XU F *et al* Advances in Plant and Animal Boron Nutrition. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-5382-5_1

Graham W A and McDonald G K (2001). Effects of zinc on photosynthesis and yield of wheat under heat stress. In: Proceedings of the 10th Australian Agronomy Conference, Hobart; Available:http://regional.org.au/au/asa/2001/2/c/graham.htm

Gupta V K and Mehla D S (1993). Depletion of micronutrients from soil and their uptake in rice-heat rotation. *J Indian Soc Soil Sci* **4**: 704-706.

Kaur A, Kaur S, Singh D, Singh S and Singh M (2020). Fortification of wheat (*Triticum aestivum* L.) with Zinc and Manganese. *J Krishi Vigyan* **8**(2): 142-149.

Kumar A (2013). Adoption behaviour and constraints in wheat production technologies for higher wheat productivity in hills of Uttarakhand. *J Krishi Vigyan* **1**(2): 6-9.

Kumar M, Singh S, Singh V, Singh K and Khanna R (2019). Effect of Zinc and Boron on Growth and Yield of Maize. *Prog Res* **14**(3): 215-221.

Rashid A, Ryan J and Estefan G (2002). Micronutrient Constraints to Crop Production in Soils with Mediterranean-type Characteristics: A Review. *J Plant Nutri* **27**(6): 959-975.

Rehm G and Sims A (2006). Micronutrients and production of hard red spring wheat. Minnesota Crop News, University of Minnesota.

Rerkasem B and Jamjod S (2004). Boron deficiency in wheat: a review. *Field Crop Res* **89**(2-3): 173–186.

Sharma M and Singh R (2020). Effect of different sowing techniques and varieties on yield of wheat (*Triticum aestivum* L.). *J Krishi Vigyan* **9**(1): 92-98.

Shukla A K, Behera S K and Prakash C (2015). Micronutrient Deficiency in Indian Soils and Approaches to Manage It. *J Plant Nutri* **13**(16): 9136.

Snowball K and Robson A D (1983). Symptoms of nutrient deficiencies: Subterranean clover and wheat. Institute of Agriculture, University of Western Australia: Nedlands, Western Australia.

Taiwo L B, Adediran J A, Akande M O, Banjoko V A and Oluwatosin G A (2001). Influence of legume fallow on soil properties and yield of maize in south-western Nigeria. *J Agri Trop Subtrop* **102**(2): 109-117.

Ziaeyana A H and Rajaiea M (2009). Combined effect of Zinc and Boron on yield and nutrients accumulation in corn. *Int J Plant Prod* **3**(3): 35-44.

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