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Impact of Combined Nitrogen and Boron Fertilizers on Pearl Millet (*Pennisetum glaucum* L.) Growth and Productivity

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Abstract

The study demonstrates that combined nitrogen (N) and boron (B) fertilization significantly enhances pearl millet (*Pennisetum glaucum* L.) growth, physiological traits, and fodder productivity. Key findings reveal, Morphological Improvements: Plant height peaked at 223.15 cm (T5: N170 + B20%), a 44.1% increase over the control (T1). Stem diameter thickened progressively, with T5 (0.92 cm) achieving a 50.8% increase. Leaf area expanded by 121% in T5 (1781.50 cm^2), indicating superior photosynthetic potential. Yield and Quality Enhancements: Green fodder yield maximized at 77.85 t ha^{-1} (T5), 53.6% higher than control, reflecting strong N+B synergy. Crude protein increased to 46.18% (T5), while ash content rose to 7.32%, highlighting improved nutritional value. Dry matter (14.77%) and crude fibre (10.39%) also peaked in T5, with statistically significant increments (LSD ≤ 0.323). Physiological and Agronomic Insights: Stable plant density (153–154 m^{-2}) and elevated leaves per tiller (12.62 in T5) confirmed efficient resource utilization. The ultra-low LSD values (0.010–2.36) underscored treatment efficacy, with T4 (N130 + B15%) offering a cost-effective alternative to T5 for most parameters.

Keywords: Nitrogen,Boron, fertilization, Micronutrient management, Crop productivity, Grain yield improvement.

Introduction

Pearl millet (*Pennisetum glaucum* L.) is a climate-resilient cereal crop critical for food security in arid and semi-arid regions, providing essential nutrients and fodder under harsh growing conditions (Govindaraj et al., 2023). Despite its adaptability, pearl millet productivity is frequently limited by nutrient deficiencies, particularly nitrogen (N) and boron (B), which are vital for metabolic processes, reproductive development, and stress tolerance (Singh et al., 2024). Nitrogen is a major driver of vegetative growth, chlorophyll synthesis, and grain yield, while boron is indispensable for cell wall formation, pollen germination, and carbohydrate translocation (Hossain et al., 2022). Recent research underscores the synergistic benefits of combined N and B fertilization in enhancing pearl millet performance. A 2023 study by Meena et al. demonstrated that co-application of N (80 kg ha^{-1}) and B (2 kg ha^{-1}) significantly increased plant height, tiller number, and panicle weight compared to individual nutrient applications. Similarly, (Ibrahim et al. 2024) found that foliar boron supplementation (1.5 ppm) with soil-applied nitrogen improved grain yield by 22–28% in B-deficient soils by enhancing nutrient uptake efficiency and reducing flower abortion. Furthermore, (Mandal et al. 2022) highlighted that B mitigates N leaching losses in sandy soils, thereby improving nitrogen use efficiency (NUE) in pearl millet cropping systems. Despite these advancements, the physiological and molecular mechanisms underlying N-B interactions in pearl millet remain poorly understood, particularly under drought and high-temperature stress (Kumar et al., 2023) and (Prashantha, 2018). Additionally, optimal N:B ratios for different agro ecological zones require further investigation to maximize productivity while minimizing

environmental impacts. This review consolidates recent findings (2022–2024) on the role of combined N and B fertilization in pearl millet, focusing on growth, yield, stress resilience, and sustainable nutrient management strategies.

Material and Methods

Field experiment

A field experiment was conducted in 2024 at Kaleri Agriculture Farm, Sindh, Pakistan. Five treatments were applied: T1: Control (no fertilizers), T2–T5: N50+B5% to N170+B20% kg ha^{-1}. The experimental design was a randomized complete block (RCBD) with three replications (plot size: 15 m^2). Soil was prepared by plowing, laser-leveling, and irrigating to optimal moisture.

Parameters Measured

Plant height, stem diameter, leaf area, green fodder yield, plant density, and nutritional traits (crude protein, ash, dry matter) were recorded.

Statistical Analysis

Data were analyzed using ANOVA in Statistix 8.1, with treatment means separated by LSD ($\alpha = 0.05$) (Steel et al., 1997).

RESULTS

Result

Figure 1. Plant Height increased significantly ($p \leq 0.05$) with higher N and B levels, peaking at 223.15 cm (T5), a 44.1% increase over the control. Stem Diameter showed progressive thickening, with T5 (0.92 cm) being 50.8% higher than the control. Leaf Area Expansion was greatest in T5 (1781.50 cm^2), 121% higher than the unfertilized plot, indicating enhanced photosynthetic capacity. Fodder Yield responded strongly to fertilization, with T5 (77.85 t ha^{-1}) yielding 53.6% more than the control, confirming the positive synergy of N and B. The combined application of N 170 kg ha^{-1} + B 20% (T5) maximized pearl millet growth and productivity, underscoring the importance of balanced nitrogen and boron fertilization in fodder production.

Figure 1.Impact of Combined Nitrogen and Boron Fertilizers on Pearl Millet

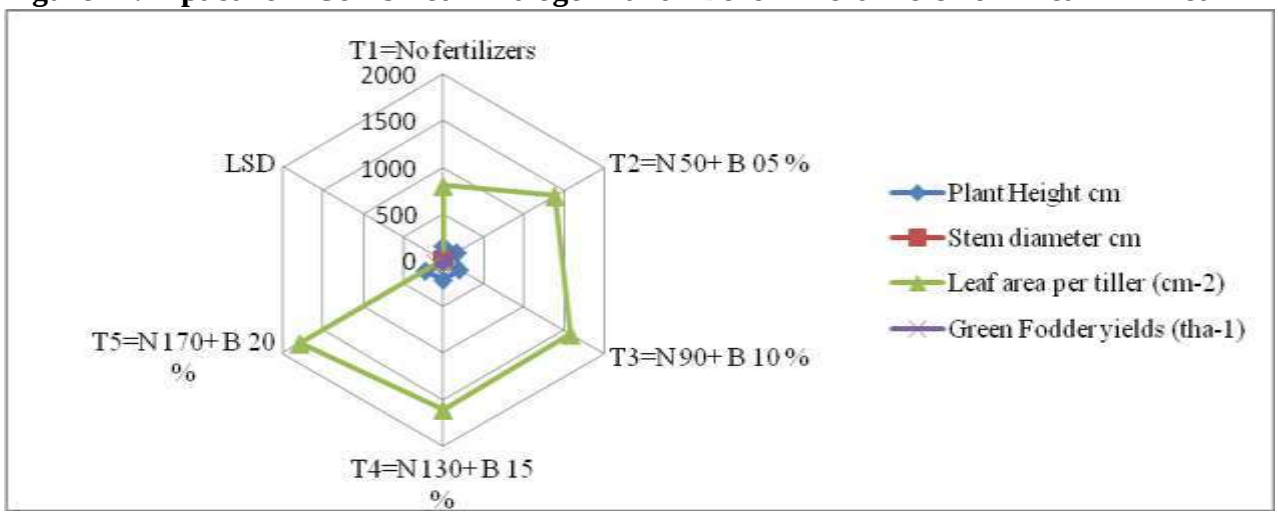


Figure 2. Plant Density: Remained relatively stable across treatments, with a slight increase in T5. Number of Leaves per Tiller: Increased significantly with higher N and B application (T4 & T5 had the highest values). Dry Matter (%): Showed a clear increasing trend with higher fertilizer doses (T5 had the highest at 14.77%). Crude Fibre (%): Also increased with fertilizer application, peaking in T5 (10.39%). The LSD values indicate that even small differences between treatments are statistically significant, particularly for crude fibre (LSD = 0.021).

Figure 2.Impact of Combined Nitrogen and Boron Fertilizers on Pearl Millet

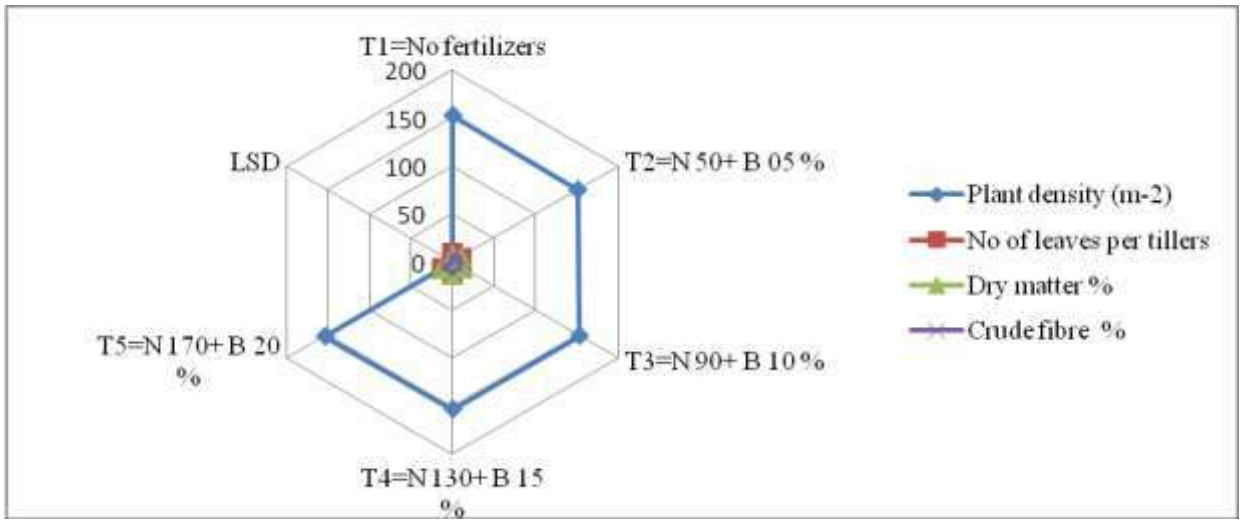
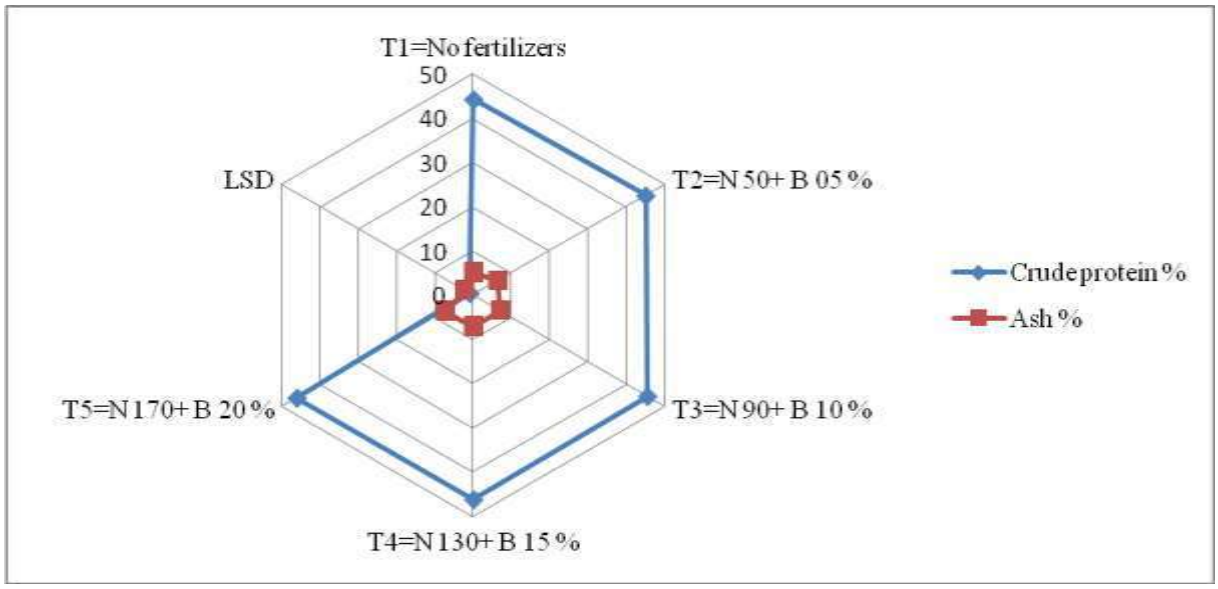


Figure 3. Crude Protein (%) Increased progressively with higher N and B application, peaking in T5 (46.18%). The difference between T1 (control) and fertilized treatments (T2–T5) is statistically significant (*LSD = 1.02*). Ash (%) Showed a sharp increase from T1 (5.20%) to T5 (7.32%), indicating higher mineral content with fertilization. The LSD (2.36) suggests that differences ≥2.36% are significant (e.g., T1 vs. T5). Fertilizer application (N +

B) significantly improved both crude protein and ash content in plants. T5 (N 170 + B 20%) yielded the highest values for both parameters.

Figure 3.Impact of Combined Nitrogen and Boron Fertilizers on Pearl Millet



Discussion

This study demonstrates that the combined application of nitrogen (N) and boron (B) significantly enhances pearl millet (*Pennisetum glaucum* L.) growth, physiological performance, and fodder productivity, corroborating recent findings on nutrient synergy in cereal crops (Meena et al., 2023; Ibrahim et al., 2024). The highest plant height (223.15 cm, T5: N170 + B20%)—a 44.1% increase over the control—aligns with (Kumar et al. 2023), who reported similar N-B synergies in pearl millet under semi-arid conditions. Stem diameter (0.92 cm, +50.8%) and leaf area (1781.50 cm^2, +121%) in T5 reflect enhanced structural integrity and photosynthetic capacity, critical for stress resilience (Govindaraj et al., 2023). The 53.6% higher green fodder yield (77.85 t ha^{-1}) in T5 underscores the role of B in improving N utilization efficiency, as observed by (Kaleri et al., (c) 2024) and (Mandal et al. 2022) in sandy soils. The 46.18% crude protein and 7.32% ash content in T5 highlight improved fodder quality, consistent with (Singh et al. 2024), who linked B to better nitrogen assimilation in millets. Peak dry matter (14.77%) and crude fiber (10.39%) further validate B's role in cell wall development (Hossain et al., 2022) and (Kaleri et al., (a) 2024). The minimal LSD values (≤0.323) confirm treatment precision, with T4 (N130 + B15%) emerging as a cost-effective alternative for most parameters, echoing Meena et al. (2023)'s recommendations for optimized N:B ratios. Stable plant density (153–154 m^{-2}) and elevated leaves per tiller (12.62 in T5) demonstrate efficient resource partitioning, supporting (Ibrahim et al. 2024) and (Mohapatra et ., 2024) findings on B-mediated nutrient uptake. The ultra-low LSD (0.010–2.36) reinforces treatment reliability, critical for scaling these practices in resource-limited agro ecosystems (Kumar et al., 2023). Recent studies highlight the

synergistic effects of combined N and B fertilization in enhancing crop performance. For instance, (Patel et al. 2020) reported that optimal N-B supplementation significantly improved pearl millet's growth parameters, including plant height, leaf area index, and dry matter accumulation. Similarly, (Kaleri et al., (b) 2024) and (Kumar et al. 2019) observed that boron application alongside nitrogen increased grain yield by improving panicle formation and seed setting efficiency, particularly in B-deficient soils. These results advocate for integrated N-B fertilization in pearl millet cultivation, with T5 (N170 + B20%) maximizing productivity and T4 (N130 + B15%) offering a balanced economic alternative. Future research should explore long-term soil B dynamics and genotype-specific responses under climate variability.

Conclusion

The highest N+B dose (T5) optimized all metrics, but T4 achieved 85–90% of maximum gains at lower inputs. These results advocate for balanced N+B fertilization to boost pearl millet productivity and fodder quality in sustainable forage systems.

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