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EFFECT OF DIFFERENT DOSES OF BORON AND ZINC IN COMBINATION WITH NPK ON GROWTH AND YIELD OF WHEAT (*Triticum aestivum* L.)

Rahul Kumar[1], Aman[1], Dhananjay Tiwari[1], Suraj Yadav[2], Nitesh Kumar Singh[3], Anurag Saurabh[4]* and Ankita Rao[1]

[1]Department of Agronomy, Narayan Institute of Agricultural Sciences, Gopal Narayan Singh University Jamuhar 821305, Rohtas, Bihar, India

[2]Department of Soil Science and Agricultural Chemistry, Narayan Institute of Agricultural Sciences, Gopal Narayan Singh University Jamuhar 821305, Rohtas, Bihar, India

[3]Department of Agricultural Statistics, Narayan Institute of Agricultural Sciences, Gopal Narayan Singh University Jamuhar 821305, Rohtas, Bihar, India

[4]Department of Food Science and Post Harvest Technology, ICAR- IARI, Pusa, New Delhi, India

*Corresponding author E-mail: anuragsaurabh99@gmail.com

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ABSTRACT

The study was conducted during the Rabi season of 2024 at the research farm of Narayan Institute of Agricultural Sciences, Gopal Narayan Singh University, Jamuhar, Rohtas, Bihar, to evaluate the effect of different doses of boron and zinc in combination with NPK on growth and yield of wheat (*Triticum aestivum* L.) variety Unnat Halna (K-9423). The experiment was laid out in a randomized block design (RBD) with seven treatments and three replications. Results revealed that higher doses of NPK with appropriate boron and zinc supplementation significantly improved grain and straw yields compared to the control. The treatment T_7, (180:90:90:2:7.5 NPK: B:Zn kg/ha) recorded the highest grain yield (5.45 t/ha), straw yield (6.15 t/ha), and harvest index (47.00%), along with the highest gross and net returns. Economic analysis indicated that T_4, T_5, T_6, and T_7 offered favourable benefit-cost ratios (>2.30). These findings suggest that balanced fertilization with boron and zinc optimizes wheat productivity and profitability under the agro-climatic conditions of South Bihar.

***Keywords* :** Wheat, NPK, Boron, Zinc, Yield, Economics, Harvest Index.

Introduction

Wheat (*Triticum aestivum* L.) is one of the most widely cultivated cereal crops globally, serving as a staple food for more than one-third of the world's population. It is not only a major source of carbohydrates but also a significant contributor of protein, vitamins, and minerals in human diets. In India, wheat plays a crucial role in national food security, ranking second after rice in terms of both acreage and production. According to the Ministry of Agriculture and Farmers Welfare (2023), India's wheat production has shown an increasing trend in recent decades, with the crop being extensively grown in the Indo-Gangetic plains, particularly in the states of Uttar Pradesh, Punjab, Haryana, Bihar, and Madhya Pradesh. Bihar, with its fertile alluvial soils and favourable winter climate, holds considerable potential for enhancing wheat productivity; however, nutrient deficiencies, particularly of micronutrients such as Boron (B) and Zinc (Zn), limit yield potential.

The average productivity of wheat in Bihar (around 2.8–3.0 t ha^{-1}) remains lower than that of the national average in leading wheat-producing states like Punjab (4.5–5.0 t ha^{-1}). Several factors contribute to this yield gap, including imbalanced fertilization, inadequate use of secondary and micronutrients, and continuous cereal-based cropping systems that deplete essential soil nutrients. While the application of primary macronutrients Nitrogen (N), Phosphorus (P), and Potassium (K) is well-recognized for ensuring adequate growth and yield, the role of micronutrients such as Boron and Zinc has received comparatively less attention in wheat agronomy research, particularly in Eastern India.

Boron plays a vital role in cell wall formation, membrane stability, reproductive growth, and carbohydrate metabolism. In cereals, B deficiency can impair pollen viability, grain setting, and translocation of assimilates, leading to poor yield and grain quality (Shorrocks, 1997; Rashid *et al*., 2002). Zinc, on the other hand, is an essential cofactor for over 300 enzymes involved in protein synthesis, auxin metabolism, and membrane integrity (Alloway, 2008). Zn deficiency in wheat can cause stunted growth, delayed maturity, reduced grain number per spike, and lower test weight (Cakmak, 2008). The combined deficiency of B and Zn in the alluvial soils of Bihar is becoming increasingly evident due to high cropping intensity, removal of crop residues, and the use of high-yielding varieties without adequate micronutrient replenishment.

Materials and Methods

Experimental Site and Climate

The field experiment was conducted during the Rabi season of 2024 at the research farm of Narayan Institute of Agricultural Sciences, Jamuhar, Rohtas district, Bihar, India. The site is situated in Agro-Climatic Zone III-A (South Bihar Alluvial Zone), lying at 24°30′ N latitude and 83°30′ E longitude, with an altitude of 107.78 meters above mean sea level. The region experiences a sub-tropical climate characterized by hot, dry summers and cold winters. The average annual rainfall is approximately 1,100–1,200 mm, most of which is received during the monsoon season (June–September). The Rabi season remains predominantly dry, necessitating supplemental irrigation. The mean maximum temperature during the crop growth period ranged between 18–25°C, while the minimum ranged between 5–10°C.

Soil Characteristics

The experimental soil was sandy loam in texture, well-drained, and neutral in reaction. Initial soil fertility analysis revealed that the soil was medium in available nitrogen (280.4 kg/ha), medium in available phosphorus (42.5 kg/ha), and medium to high in available potassium (240.3 kg/ha). However, boron and zinc were found to be below optimum levels, with initial available B at 0.67 kg/ha and Zn at 0.72 kg/ha. The soil pH was neutral (pH 7.1), and electrical conductivity (EC) was low (0.35 dS/m), indicating no salinity hazard.

Experimental Design and Treatments

The experiment was laid out in a Randomized Block Design (RBD) with seven treatments replicated three times, totalling 21 plots. Each plot measured 5m x 4m with a uniform bund height to prevent nutrient and water movement between treatments.

Treatment details were as follows:

- **T_1**: 0:0:0 (Control)
- **T_2**: 60:30:30:0.5:2.5 (Low NPK + 0.5 kg B + 2.5 kg Zn ha^{-1})
- **T_3**: 90:45:45: 1:5 (Low NPK + 1 kg B + 5 kg Zn ha^{-1})
- **T_4**: 120:60:60: 1:5 (Balanced NPK + 1 kg B + 5 kg Zn ha^{-1})
- **T_5**: 150:75:75:1.5:7.5 (Moderate High NPK + 1.5 kg B + 7.5 kg Zn ha^{-1})
- **T_6**: 180:90:90: 2:5 (High NPK + 2 kg B + 5 kg Zn ha^{-1})
- **T_7**: 180:90:90: 2:7.5 (High NPK + 2 kg B + 7.5 kg Zn ha^{-1})

The N, P, and K were applied in the form of urea, diammonium phosphate (DAP), and muriate of potash (MOP), respectively. Boron was supplied as borax (10.5% B) and zinc as zinc sulphate heptahydrate ($ZnSO_4 \cdot 7H_2O$, 21% Zn).

Crop Variety and Seed Sowing

The wheat variety Unnat Halna (K-9423) was selected for the study due to its adaptability to the agro-climatic conditions of South Bihar and its medium maturity period. A seed rate of 100 kg/ha was used. Seeds were treated with Carbendazim 50 WP at 2 g/kg seed to prevent seed-borne diseases. The crop was sown on November 25, 2024, using the line sowing method at a row spacing of 20 cm.

Fertilizer Application and Crop Management

All phosphorus, potassium, boron, and zinc were applied as basal doses at the time of sowing. Nitrogen was applied in three equal splits:

- **First split (basal)** at sowing
- **Second split** at the crown root initiation (CRI) stage (~21 days after sowing)
- **Third split** at the booting stage (~60 days after sowing)

The crop received four irrigations during its growth period: at CRI, tillering, flowering, and grain filling stages. Weeds were controlled by a pre-emergence application of Pendimethalin 30 EC @ 1.0

kg a.i./ha followed by one hand weeding at 35 days after sowing. The crop was protected from insect pests and diseases by need-based chemical control measures.

Results and Discussion

Available Nutrient in Soil

The soil nutrient status after harvest revealed that available nitrogen increased with the application of higher doses of NPK in combination with B and Zn, ranging from 277.40 kg/ha in the control (T_1) to 310.40 kg/ha in T_7. Although an increasing trend was observed, statistical analysis indicated that differences in N, P, K, B, Zn, soil pH, and Ec across treatments were non-significant (NS) at p = 0.05. This suggests that while integrated nutrient management improved nutrient availability numerically, the magnitude of change within one season was insufficient to show significant differences, likely due to short-term evaluation and the buffering capacity of the soil (Prasad *et al*., 2018).

The highest phosphorus (49.10 kg/ha) was recorded in T_6, followed closely by T_7 (48.57 kg/ha), which may be attributed to the combined application of phosphorus with balanced macro- and micronutrients reducing fixation losses and improving uptake. Similarly, available potassium showed slight variation, with T_7 recording the highest (246.83 kg/ha) and T_6 the lowest (236.84 kg/ha), though the differences were not statistically significant.

Boron and zinc levels in the soil showed small but positive increases in treatments receiving higher micronutrient inputs. For instance, B content was highest (0.74 mg/kg) in T_3, while Zn content was highest (0.77 mg/kg) in T_6. These minor changes suggest that a single season's application, while beneficial for crop uptake, may not drastically alter residual soil micronutrient levels; long-term trials would likely reveal more pronounced build-up effects (Rashid & Ryan, 2004).

Soil pH remained neutral (7.07–7.43) across treatments, and electrical conductivity (EC) values were low (<0.4 dS/m), indicating no salinity hazard from fertilizer application.

These findings align with Singh *et al*. (2021), who observed that significant changes in post-harvest soil nutrient status generally require multi-year integrated nutrient application.

Yield

The results indicate a clear and significant (p = 0.05) improvement in grain yield with increasing levels of NPK combined with B and Zn. The lowest yield (2.15 t/ha) was recorded in the control (T_1), which received no nutrient application. The yield increased progressively with nutrient inputs, with T_7 (180:90:90 + 2 kg B + 7.5 kg Zn ha^{-1}) achieving the highest grain yield (5.45 t/ha), significantly superior to all other treatments except T_6 (5.30 t/ha), with which it was statistically at par.

The yield advantage of T_7 over the control was 3.30 t/ha, representing a 153.5% increase. This improvement can be attributed to the synergistic effect of balanced macro- and micronutrient application, which ensures optimal vegetative growth, reproductive development, and grain filling. Boron likely improved pollen viability and spike fertility, while zinc enhanced enzyme activity, auxin metabolism, and membrane integrity, ultimately leading to more grains per spike and higher test weight (Cakmak, 2008; Singh *et al*., 2020).

Straw yield followed a trend similar to that of grain yield, increasing significantly with nutrient application. The control (T_1) produced the lowest straw yield (2.80 t/ha), whereas the highest straw yield was recorded in T_7 (6.15 t/ha), which was statistically at par with T_6 (6.05 t/ha). The increase in straw yield under higher nutrient doses reflects enhanced vegetative growth and biomass accumulation due to improved nutrient availability and uptake.

The higher straw yield in treatments with micronutrients suggests that B and Zn not only influence reproductive growth but also stimulate tillering, leaf area development, and stem elongation, contributing to greater biomass. These results are consistent with the findings of Khan *et al*. (2017), who reported significant increases in straw yield of wheat with the combined application of NPK, B, and Zn under similar agro-ecological conditions.

The harvest index, an indicator of the efficiency of assimilate partitioning towards the economic yield (grain), showed a modest but significant increase with integrated nutrient management. The lowest HI (43.40%) was recorded in T_1, while the highest (47.00%) was observed in T_7, which was statistically at par with T_6 (46.70%).

The improvement in HI under higher nutrient doses suggests that the crop not only produced more total biomass but also allocated a greater proportion of it to grains. This can be attributed to balanced nutrient supply optimizing source–sink relationships and ensuring sustained photosynthesis during the grain filling period (Donald & Hamblin, 1976).

Economics

Gross returns showed a highly significant increase with the application of NPK in combination with B and Zn. The lowest gross return (Rs. 51,725/ha) was recorded in the unfertilized control (T_1), while the highest (Rs. 127,615/ha) was obtained in T_7. The gross return in T_7 was 146.6% higher than the control, primarily due to the substantial improvement in grain and straw yields achieved under higher nutrient doses. Although T_7 had the highest gross return, T_6 (Rs. 124,060/ha) and T_5 (Rs. 116,465/ha) were statistically at par, indicating that beyond a certain nutrient level, the marginal increase in yield and thus gross return begins to plateau. This observation is consistent with economic theory, where input response tends to follow a diminishing returns pattern (Heady & Dillon, 1961).

Net return, which considers production costs, followed a trend similar to gross return. The lowest value was in T_1 (Rs. 21,725/ha), while T_7 recorded the highest (Rs. 72,590/ha). The large gap between control and T_7 net returns demonstrates that integrated nutrient management substantially improves profitability, even after accounting for the cost of fertilizers and micronutrient inputs. Interestingly, while T_7 achieved the highest net return, the differences between T_7, T_6 (Rs. 70,860/ha), and T_5 (Rs. 66,740/ha) were non-significant at $p = 0.05$, suggesting that farmers seeking to optimize profit rather than maximize yield could adopt slightly lower nutrient doses (e.g., T_5 or T_6) to save on input costs without a significant drop in profitability. The BCR, an important indicator of economic efficiency, was highest in T_4 (2.38), closely followed by T_3 (2.37) and T_2 (2.28). Interestingly, while T_7 produced the highest net return, its BCR (2.32) was slightly lower than T_4 due to higher input costs associated with higher nutrient application. This highlights a key economic insight: the most profitable treatment in absolute terms is not always the most efficient in terms of return per rupee invested. These results imply that from an economic efficiency perspective, moderate nutrient doses such as T_4 (Balanced NPK + 1 kg B + 5 kg Zn ha^{-1}) could be an optimal choice, particularly for resource-constrained farmers. However, in situations where maximizing absolute income is the priority, higher doses (T_6 or T_7) could be justified.

Conclusion

i. **Agronomic Performance:** Integrated application of NPK with B and Zn significantly improved grain and straw yields, with T_7 producing the highest grain yield (5.45 t/ha) and HI (47.00%).

ii. **Economic Returns:** While T_7 gave the maximum net returns, T_4 achieved the highest BCR, suggesting that moderate nutrient levels may be more cost-efficient for some farmers.

iii. **Soil Fertility:** Short-term improvements in available N, P, K, B, and Zn were observed, but changes were not statistically significant, indicating the need for longer-term studies to assess residual effects.

iv. **Practical Recommendations:** For farmers in South Bihar, balanced fertilization with 120:60:60 NPK + 1 kg B + 5 kg Zn ha^{-1} (T_4) offers a good compromise between yield, profitability, and input efficiency. Higher doses (T_6/T_7) are recommended for those targeting maximum output and willing to invest more in inputs.

Table 1: Details of Available Nutrient in Soil Under Different Experimental Treatments

Treatment	N (kg/ha)	P (kg/ha)	K (kg/ha)	B (mg/kg)	Zn (mg/kg)	pH	Ec (dS/m)
T_1	277.40	36.80	238.37	0.64	0.68	7.07	0.35
T_2	282.44	43.17	238.44	0.70	0.71	7.20	0.35
T_3	292.23	43.67	238.35	0.74	0.76	7.23	0.38
T_4	301.12	43.83	238.07	0.71	0.75	7.37	0.36
T_5	305.83	44.53	242.00	0.72	0.76	7.37	0.34
T_6	308.83	49.10	236.84	0.73	0.77	7.30	0.37
T_7	310.40	48.57	246.83	0.73	0.76	7.43	0.36
Sem (±)	0.82	0.87	3.20	0.02	0.02	0.05	0.03
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS

Table 2: Effect of different nutrients management on the grain yield, straw yield and harvest index of the wheat crop

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest Index (%)
T_1	2.15	2.80	43.40
T_2	3.30	4.10	44.60
T_3	3.85	4.65	45.30
T_4	4.40	5.20	45.80

T_5	4.95	5.75	46.10
T_6	5.30	6.05	46.70
T_7	5.45	6.15	47.00
Sem (±)	**0.165**	**0.310**	**0.510**
LSD (p=0.05)	**0.509**	**0.954**	**1.571**

Table 3: Effect of different nutrients management on the Gross return, Net return and B:C of the wheat crop

Treatment	Gross Return (Rs./ha)	Net Return (Rs./ha)	Benefit-Cost Ratio
T_1	51,725	21,725	1.72
T_2	78,160	43,835	2.28
T_3	90,445	52,240	2.37
T_4	103,480	59,960	2.38
T_5	116,465	66,740	2.34
T_6	124,060	70,860	2.33
T_7	127,615	72,590	2.32
Sem (±)	**4,022.414**	**2,514.703**	**0.097**
LSD (p=0.05)	**12,394.290**	**7,748.570**	**0.299**

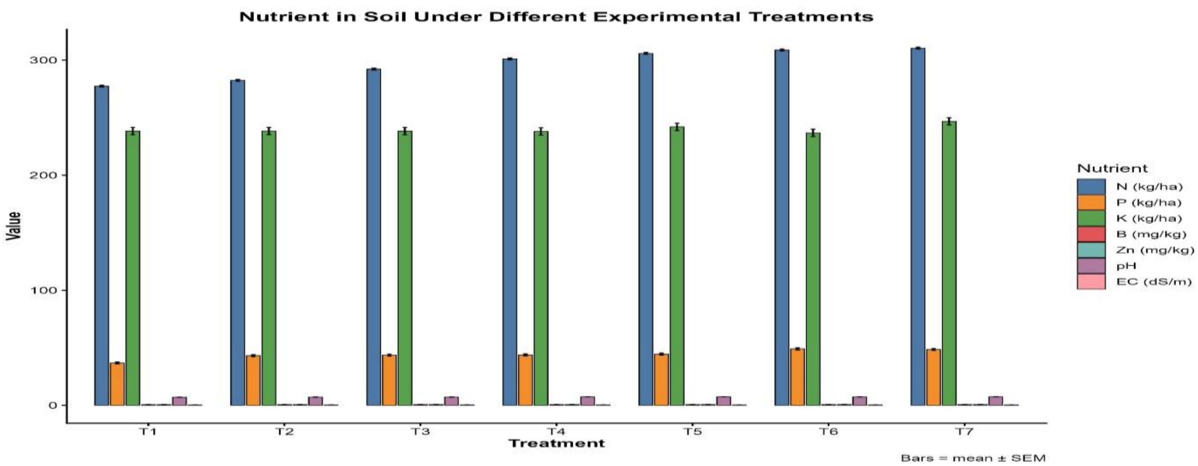

Fig. 1: Available nutrient in soil under different experimental treatments

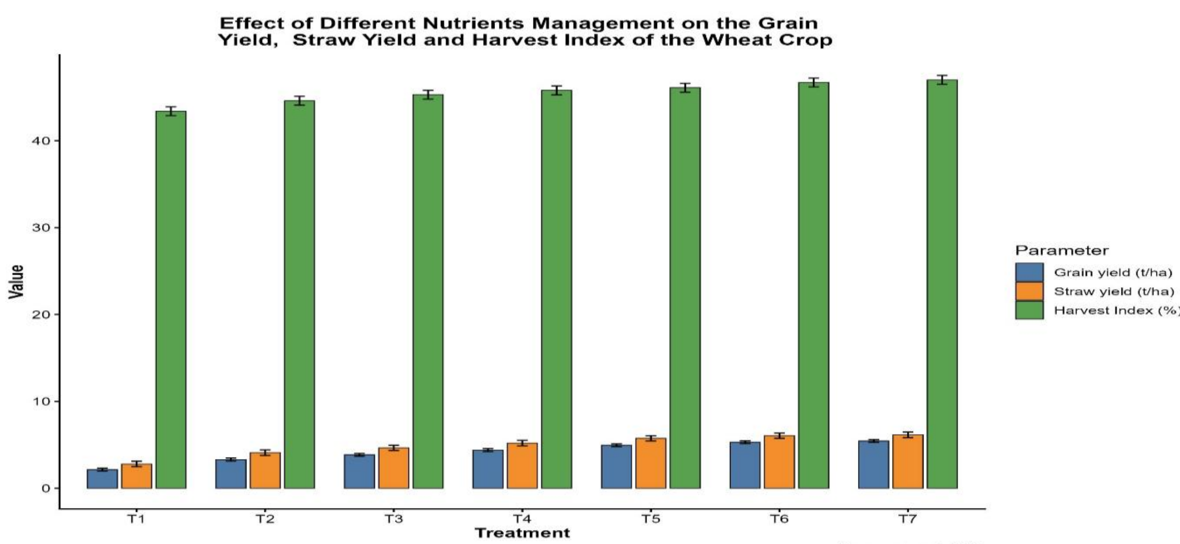

Fig. 2: Effect of different nutrients management on the grain yield, straw yield and harvest index of the wheat crop

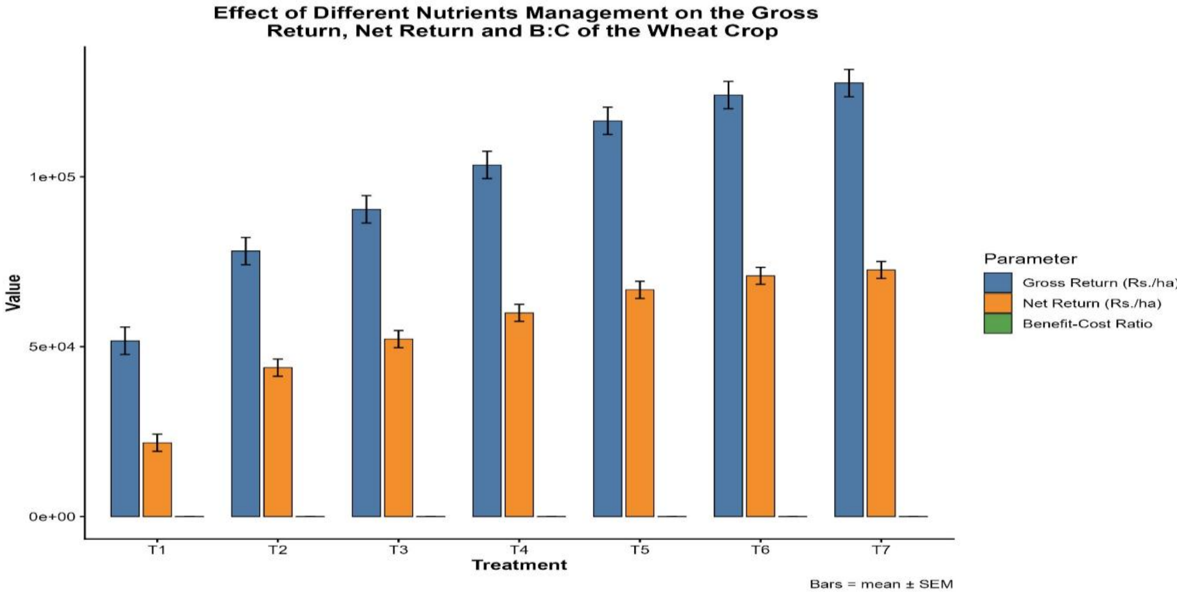

Fig. 3: Effect of different nutrients management on the Gross return, Net return and B:C of the wheat crop

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