E-ISSN: 2618-0618
P-ISSN: 2618-060X

NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(1): 208-212
Received: 19-11-2025
Accepted: 21-12-2025

Vipul Vikash
Ph.D. Scholar, Faculty of Agricultural Sciences and Technology, Mansarovar Global University, Sehore, Madhya Pradesh, India

CL Gour
Assistant Professor, Faculty of Agricultural Sciences and Technology, Mansarovar Global University, Sehore, Madhya Pradesh, India

Corresponding Author:
Vipul Vikash
Ph.D. Scholar, Faculty of Agricultural Sciences and Technology, Mansarovar Global University, Sehore, Madhya Pradesh, India

Nutrient optimization in maize: Evaluating boron and nitrogen interaction for better yield and quality

Vipul Vikash and CL Gour

DOI: https://www.doi.org/10.33545/2618060X.2026.v9.i1c.4627

Abstract
This study evaluated the effect of integrated nitrogen management (INM) strategies combined with Boron supplementation on maize growth and development. Fifteen treatment combinations involving full and split applications of urea, farmyard manure (FYM), vermicompost (VC), and Azotobacter, along with varying levels of Boron, were tested. Results revealed that maize plant height and vegetative growth were significantly influenced by both nitrogen management and Boron application. Full nitrogen through urea with Boron at 3 kg/ha (T_2) produced the tallest plants at all growth stages, while split applications with organic sources and Boron also enhanced growth, though to a lesser extent. Among all treatments, 50% urea + 50% VC with Boron at 2 kg/ha (T_7) was most effective in sustaining both vegetative vigor and reproductive growth. The findings underscore that optimizing the combination of inorganic and organic nitrogen sources along with Boron supplementation can substantially improve nutrient use efficiency, vegetative growth, and overall maize productivity.

Keywords: Maize, integrated nitrogen management, boron application, nutrient use efficiency, growth attributes, yield and quality

Introduction

The term Zea mays originates from two distinct languages. The word Zea is derived from ancient Greek, where it served as a generic term for cereals and grains. Some agronomists interpret it as meaning "sustaining life." The word mays is traced back to the Taino language, signifying "life giver." The exact center of origin of maize (Zea mays L.) is still debated; some scholars attribute it to Peru, Bolivia, and Ecuador, while others identify Southern Mexico and Central America. Today, maize is cultivated widely across the globe, including in the United States, China, Brazil, Argentina, Mexico, Poland, France, South Africa, Romania, the former USSR, Yugoslavia, and India. In India, the major maize-producing states are Gujarat, Rajasthan, Punjab, Haryana, Bihar, Madhya Pradesh, Uttar Pradesh, Andhra Pradesh, Himachal Pradesh, and Jammu & Kashmir. Notably, Poland has reported attainable yields as high as 11-12 t/ha.

Agronomically, maize can be cultivated throughout the year owing to its photo-thermo-insensitive nature, which makes it highly adaptable to diverse climatic conditions. For this reason, it is often referred to as the "Queen of Cereals." With its high genetic yield potential, maize surpasses other cereals, earning the name "miracle crop." As a C4 plant, it efficiently converts solar energy into dry matter, resulting in higher biomass production. However, being a heavy feeder of nutrients, its productivity is highly dependent on appropriate nutrient management practices.

The maintenance and enhancement of soil fertility along with efficient nutrient delivery to plants are essential for sustaining target productivity levels. Integrated Nutrient Management (INM) was developed on the principles of eco-friendly and balanced fertilization, with an emphasis on optimizing nutrient supply from all potential sources both inorganic and organic for achieving predetermined crop yield targets. This approach integrates the efficient use of soil, water, organic matter, and other natural resources.

Another important organic amendment is vermicompost, produced through the interaction of microorganisms and earthworms under mesophilic conditions (up to 25 °C). Vermicompost is a stabilized material with a low C:N ratio, high microbial and enzymatic activity, fine particulate structure, and excellent moisture-holding capacity. It contains essential nutrients such as N, P, K, Ca, and Mg in plant-available forms (Lavelle & Martin, 1992) [16]. Application of recommended fertilizer doses (RDF) in combination with farmyard manure (FYM) has been found to improve maize germination and plant height (Shakoor *et al*., 2015) [11]. Similarly, higher levels of FYM application have been reported to enhance germination percentage (Shahna & Sheikh).

Boron is one of the most limiting micronutrients in soils and its deficiency significantly affects the productivity of various crops, including cereals, with maize being particularly sensitive to micronutrient deficiencies (Broadley *et al*., 2007) [5]. Boron plays a crucial role in healthy crop growth as it is required for meristematic cell formation and division at root and shoot tips, carbohydrate metabolism and translocation, maintenance of plasma membrane integrity, pollen tube initiation and elongation, successful pollination, and ultimately, healthy seed formation (Siddiky *et al*., 2007) [17]. Globally, after zinc, boron deficiency ranks as the second most critical micronutrient constraint to soil fertility.

Methods and Materials

The experiment was conducted at Mansarovar Global University, Bilkisganj, Sehore, M.P., during the Kharif seasons of 2023 and 2024 to evaluate the effect of nutrient management practices on crop performance. The study comprised 15 treatments involving Urea, Vermicompost (VC), Farm Yard Manure (FYM), Azotobacter, and Boron, each replicated three times, resulting in a total of 45 plots. The treatments were randomly assigned in a Randomized Block Design (RBD) as follows:

- **T_1:** 100% N through Urea + Boron @ 2 kg/ha
- **T_2:** 100% N through Urea + Boron @ 3 kg/ha
- **T_3:** 100% N through Urea + Boron @ 4 kg/ha
- **T_4:** 50% N through Urea + 50% N through FYM + Boron @ 2 kg/ha
- **T_5:** 50% N through Urea + 50% N through FYM + Boron @ 3 kg/ha
- **T_6:** 50% N through Urea + 50% N through FYM + Boron @ 4 kg/ha
- **T_7:** 50% N through Urea + 50% N through VC + Boron @ 2 kg/ha
- **T_8:** 50% N through Urea + 50% N through VC + Boron @ 3 kg/ha
- T_9: 50% N through Urea + 50% N through VC + Boron @ 4 kg/ha
- **T_{10}:** 50% N through Urea + 25% N through FYM + 25% N through VC + Boron @ 2 kg/ha
- **T_{11}:** 50% N through Urea + 25% N through FYM + 25% N through VC + Boron @ 3 kg/ha
- **T_{12}:** 50% N through Urea + 25% N through FYM + 25% N through VC + Boron @ 4 kg/ha
- **T_{13}:** 50% N through Urea + 25% N through FYM + 25% N through Azotobacter + Boron @ 2 kg/ha
- **T_{14}:** 50% N through Urea + 25% N through FYM + 25% N through Azotobacter + Boron @ 3 kg/ha
- **T_{15}:** 50% N through Urea + 25% N through FYM + 25% N through Azotobacter + Boron @ 4 kg/ha

This experimental setup allowed for the assessment of the individual and combined effects of chemical, organic, and biofertilizer sources of nitrogen along with varying Boron levels on crop growth and productivity.

Result and Discussion

1. Plant Hight

The influence of various integrated nitrogen management (INM) strategies combined with different Boron (B) levels on maize plant height measured at 20, 40, 60, and 80 days after sowing (DAS). A total of 15 treatment combinations (T_1-T_{15}) were tested, including 100% nitrogen through urea, split combinations of urea with farmyard manure (FYM), vermicompost (VC), and biofertilizer (Azotobacter), each supplemented with Boron at 2, 3, and 4 kg/ha.

At 20 DAS, plant height ranged from 6.05 cm (T_4: 50% N through urea + 50% N through FYM + B 2 kg/ha) to 11.3 cm (T_2: 100% N through urea + B 3 kg/ha), indicating early vegetative growth response to nitrogen and Boron application.

By 40 DAS, the height varied from 29.6 cm (T_4) to 49.6 cm (T_2), showing that treatments with higher Boron levels (3 kg/ha) and full urea application promoted better growth.

At 60 DAS, plant height ranged between 111.2 cm (T_4) and 138.45 cm (T_2), reflecting continued enhanced growth in treatments with optimal nitrogen-Boron combinations.

By 80 DAS, the maximum plant height was recorded in T_2 (197.05 cm), while the minimum was in T_4 (177.05 cm), highlighting the cumulative effect of INM and Boron on maize growth.

Overall, treatments combining 100% nitrogen through urea with Boron at 3 kg/ha (T_2) consistently produced taller plants at all growth stages. Among the INM combinations, integrating urea with FYM, VC, or Azotobacter supplemented with Boron at 3 kg/ha also showed a substantial positive effect on plant height. The table also provides critical difference (CD) at 5% and standard error of mean (SEm) values, indicating statistical significance and reliability of observed differences.

2. Crop Growth Rate

The effect of integrated nitrogen management and boron application on the Crop Growth Rate (CGR) of maize at different growth stages (0-20, 20-40, 40-60, and 60-80 DAS). The results highlight substantial variations in CGR across treatments, depending on the nitrogen source combination and boron level.

0-20 DAS (Initial Growth Phase)

- During the early growth phase, CGR values were relatively low across all treatments, ranging from 0.437 (T_4) to 0.865 (T_2).
- Treatments with 100% urea combined with higher boron (3 kg/ha) recorded higher early growth rates, indicating that readily available nitrogen from urea supported rapid early seedling establishment.
- In contrast, treatments involving FYM and VC (organic sources) showed slightly lower CGR at this stage, suggesting that nutrient mineralization from organic matter was slower in the initial phase.

20-40 DAS (Vegetative Growth Phase)

- A notable increase in CGR was observed during this interval, with values ranging from 1.770 (T_6) to 3.983 (T_2).
- Treatments with 100% urea + 3 kg boron (T_2) and integrated use of urea with FYM/VC + 3 kg boron (T_5, T_8, T_{14}) performed better.
- This indicates that boron application at 3 kg/ha enhanced vegetative growth, possibly by improving cell wall development, photosynthesis, and nutrient uptake efficiency.

40-60 DAS (Peak Vegetative to Reproductive Transition Phase)

- This period showed the highest CGR values across treatments, ranging between 6.995 (T_3) and 13.43 (T_6).
- The integrated treatments with 50% urea + 50% FYM/VC (T_4, T_6, T_7, T_9) displayed superior CGR compared to sole urea treatments.
- For instance, T_6 (50% Urea + 50% FYM + 4 kg boron) recorded the highest CGR (13.43), suggesting that a balanced nutrient supply from both inorganic and organic sources provided sustained nitrogen availability during the rapid vegetative growth stage.
- This trend highlights the synergistic role of organics (slow nutrient release, improved soil health) and boron in supporting vigorous growth during critical crop development stages.

60-80 DAS (Reproductive to Grain-Filling Phase)

- The CGR values peaked again at this stage, ranging from 25.76 (T_4) to 58.7585 (T_7).
- Treatments with vermicompost integration (T_7 and T_{10}) showed the highest CGR values, indicating that VC possibly enhanced nutrient mineralization and improved soil microbial activity during the reproductive stage.
- Particularly, T_7 (50% Urea + 50% VC + 2 kg boron) outperformed all other treatments with a CGR of 58.76, followed by T_{10} (52.79) and T_{11} (51.39).
- These results demonstrate that combining organic and inorganic sources ensures a continuous nutrient supply, supporting both vegetative and reproductive processes.

General Trend Analysis

1. Sole urea treatments (T_1-T_3) supported rapid early growth but declined in later stages, indicating limited residual effect.
2. Integrated nutrient management (INM) with FYM, VC, and Azotobacter consistently improved growth performance, especially in the later stages.
3. Boron application at 2-3 kg/ha proved more beneficial than higher levels (4 kg/ha), suggesting that moderate boron is optimal for maize growth, while excessive levels may not confer additional benefits.
4. Vermicompost-based treatments (T_7, T_8, T_9, T_{10}, T_{11}) consistently showed higher CGR at 60-80 DAS, highlighting the role of VC in enhancing nutrient availability during grain filling.

Quality Parameter - Protein Content in Maize

Maize (Zea mays L.) is a globally important staple crop, providing both carbohydrates and protein, the latter being essential for human nutrition and livestock feed. The protein content in maize grains is influenced by genotype, soil fertility, nutrient management, and environmental conditions. Enhancing protein concentration is particularly significant in regions where maize is a major dietary component, contributing to improved nutritional security.

The highest protein content (10.64%) was recorded under T_8 (50% N through urea + 50% N through vermicompost + Boron @ 3 kg/ha). Other effective treatments included T_{11} (10.44%), T_5 (10.25%), and T_2 (10.22%), highlighting that integrating organic nutrient sources with urea and applying moderate boron levels enhanced nitrogen uptake and its conversion into grain protein. These improvements are likely due to more balanced nutrient release, enhanced soil microbial activity, and boron's role in enzymatic functions and protein metabolism.

The lowest protein contents were observed in T_4 (8.60%), T_7 (8.55%), and T_9 (8.92%), which either had lower boron application (2 kg/ha) or less synchronized nutrient availability, limiting nitrogen assimilation and protein formation. Across the two experimental years, protein percentages were slightly higher in 2024 than in 2023; however, these differences were not statistically significant (CD non-significant), indicating that treatment effects were more influential than seasonal variations.

In conclusion, substituting a portion of urea with organic sources (FYM or vermicompost) combined with boron at 3 kg/ha proved most effective in improving maize protein content. This integrated nutrient management strategy enhances grain quality, supports soil health, and promotes sustainable crop production.

Table 1: Effect of Integrated Nitrogen Management with Boron application on plant height at 20, 40, 60 & 80 DAS

Treatment	Treatment Combination	Plant Height (cm) 20 DAS Average	Plant Height (cm) 40 DAS Average	Plant Height (cm) 60 DAS Average	Plant Height (cm) 80 DAS Average
T_1	100 % N through Urea + Boron @2 kg/ ha.	6.8	33.45	117	182.1
T_2	100% Nthrough Urea + Boron@ 3 kg/ ha.	11.3	49.6	138.45	197.05
T_3	100% N through Urea + Boron@ 4 kg/ ha.	6.6	33.65	115.25	180.65
T_4	50% Nthrough Urea + 50% N through FYM + Boron@ 2 kg/ha	6.05	29.6	111.2	177.05
T_5	50 % N through Urea + 50% Nthrough FYM + Boron @ 3 kg/ha	9.475	45.95	135.95	191.95
T_6	50 % N through Urea + 50% N through FYM + Boron @ 4 kg/ ha	6.4	32.85	113.1	179.65
T_7	50 % N through Urea + 50% Nthrough VC + Boron@ 2 kg/ ha	6.9	33.1	119.2	183.1
T_8	50 % N through Urea + 50 % N through VC + Boron @ 3 kg/ ha	9.6	42.6	133.9	190.6
T_9	50 % N through Urea + 50 % N through VC + Boron@ 4 kg/ ha	7.05	33.15	122.45	185.9
T_{10}	50 % N through Urea + 25 % N through FYM + 25% N through VC + Boron@ 2 kg/ ha	8.2	40.05	128.2	187.1
T_{11}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron @ 3 kg/ha	9.5	42.9	132	188.65
T_{12}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron@ 4 kg/ha	7.3	39.25	125.4	183.4
T_{13}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron @ 2 kg/ha	7.05	39.75	127.5	186.75
T_{14}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron@ 3 kg/ha	10.35	48.2	137.05	193.2
T_{15}	50 % Nthrough Urea + 25 % N through FYM + 25 % N through *Azotobactor*+ Boron@ 4 kg/ha	7	37.8	123.4	186.2
	CD (5%)	0.6075	1.232	1.0055	1.019
	SE(m)	0.209	0.4235	0.3455	0.35

Table 2: Effect of Integrated Nitrogen Management with Boron application on CGR of Maize between the intervals of 0-20, 20-40, 40-60 & 60-80 DAS.

Treatment	Treatment Combination	CGR at 0-20 DAS	CGR at 20-40 DAS	CGR at 40-60 DAS	CGR at 60-80 DAS
T_1	100 % N through Urea + Boron @ 2 kg/ha	0.495	2.373	8.065	33.9065
T_2	100% N through Urea + Boron @ 3 kg/ ha	0.865	3.983	11.13	44.18
T_3	100% N through Urea + Boron @ 4 kg/ha	0.732	1.937	6.995	46.162
T_4	50% N through Urea + 50% N through FYM + Boron @ 2 kg/ ha	0.437	2.028	12.615	25.76
T_5	50 % N through Urea + 50% through FYM + Boron 3 kg/ ha	0.565	3.233	9.065	47.617
T_6	50 % N through Urea + 50% N through FYM + Boron@ 4 kg/ ha	0.771	1.770	13.43	41.563
T_7	50 % N through Urea + 50% Nthrough VC + Boron @ 2 kg/ ha	0.79	1.977	11.23	58.7585
T_8	50 % N through Urea + 50 % N through VC + Boron @ 3 kg/ha	0.552	3.017	8.415	43.352
T_9	50 % N through Urea + 50 % N through VC + Boron @ 4 kg ha	0.695	2.263	12.5	28.855
T_{10}	50 % N through Urea + 25 % N through FYM + 25% N through VC + Boron @ 2 kg/ ha	0.818	2.613	10.68	52.792
T_{11}	50 % N through Urea + 25 % Nthrough FYM + 25 % N through VC + Boron @ 3 kg/ ha	0.825	2.790	8.065	51.395
T_{12}	50 % N through Urea + 25 % Nthrough FYM + 25 % N through VC + Boron @ 4 kg/ ha	0.73	2.573	9.58	30.8965
T_{13}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron @2 kg/ha	0.765	2.700	11.56	33.213
T_{14}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron@ 3 kg/ ha	0.8115	3.350	8.065	45.312
T_{15}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron @ 4 kg/ha	0.655	2.370	9.615	36.123
	CD (5%)	0.102	0.185	NA	12.662
	SE(m)	0.035	0.074	2.725	6.5185

Conclusion

The study concludes that maize growth is significantly enhanced by integrated nitrogen management combined with Boron supplementation. Full nitrogen through urea with Boron (T_2) produced the tallest plants, while split applications of urea with FYM, vermicompost, or Azotobacter, along with Boron, also improved growth. Integrated approaches, especially 50% urea + 50% vermicompost with Boron at 2 kg/ha (T_7), effectively supported both vegetative vigor and reproductive development. These results highlight that optimizing nitrogen sources and Boron application can substantially improve maize growth and productivity.

The study demonstrated that integrated nutrient management, combining partial urea substitution with organic sources (FYM or vermicompost) and boron application at 3 kg/ha, significantly enhanced the protein content of maize grains. Treatments with balanced nutrient availability and adequate boron (T_8, $T_1$1, T_5, and T_2) showed superior protein accumulation, while lower boron levels or less synchronized nutrient supply resulted in reduced protein content. Seasonal variations had minimal impact compared to treatment effects. Therefore, adopting this integrated nutrient management approach can improve maize grain quality, support soil health, and contribute to sustainable and nutritionally secure maize production.

References

1. Ahmed N, Parry GA, Bhat SA, Rasool F. Impact of integrated nutrient management on growth and yield of maize at high altitude cold areas of Kashmir. Adv Life Sci. 2016;5(9):3534-3536.
2. Ali S, Noorudin A, Ameri-Al HA Baydaa. Agronomic efficiency of Zn-DTPA and boric acid fertilizers applied in calcareous Iraqi soil. Iraqi J Agric Sci. 2015;46(6):1117-1122.
3. Aliyas A, Usman M, Ullah E, Warraich EA. Effects of different phosphorus levels on growth and yield of two cultivars of maize (*Zea mays* L.). Int J Agric Biol. 2023;5(4):632-634.
4. Baharvand Z, Zahedi H, Sharghi Y, Seifolahinic S. Comparative assessment of conventional and organic nutrient management on yield and yield components of three corn cultivars. Int J Biosci. 2014;4:281-287.
5. Broadley M, Ali H, Kendig A. Impact of nitrogen and boron application on growth and yield of maize (*Zea mays* L.). Crop J Res Sci. 2007;15(2):153-157.
6. Dutta D, Kumar V, Singh S. Effect of nitrogen, FYM and *Azotobacter* interaction on rhizospheric population of *Azotobacter* and yield of maize in Mollisol of Uttarakhand. Bio-Sci Bioeng Biotechnol. 2014;1:11-15.
7. Hassim M, Dhar S, Vyas AK, Pramesh V, Kumar V. Integrated nutrient management in maize (*Zea mays* L.)-wheat (*Triticum aestivum* L.) cropping system. Indian J Agron. 2015;60(3):352-359.
8. Omar AEA. Effect of FYM and phosphorus fertilization on yield and its components of maize (*Zea mays* L.). Asian J Crop Sci. 2014;6:1-12.
9. Raman R, Suganaya K. Effect of integrated nutrient management on the growth and yield of hybrid maize. Open Access J Agric Res. 2018;3(2).
10. Sah ST, Hussain T, Zamir MS, Ibni A, Waseem MW, Asghav M, *et al*. Growth and yield response of maize (*Zea mays* L.) to organic and inorganic sources of nitrogen. Pak J Life Soc Sci. 2019;7(2):108-111.
11. Shakoor A, Ashraf M, Sah L, Ali A, Khan A, Sher A, *et al*. Impact of farmyard manure, nitrogen, phosphorus and potassium on maize crop. Acad Res J Agric Sci Res. 2015;3(8):219-223.
12. Singh L, Kumar S, Singh K, Singh D. Effect of integrated nutrient management on growth and yield attributes of maize (*Zea mays* L.). J Pharmacogn Phytochem. 2017;6(5):1625-1628.
13. Tetrawal JP, Baldev R, Meena DS. Effect of integrated nutrient management on productivity, profitability, nutrient uptake and soil fertility in rain-fed maize (*Zea mays* L.).

Indian J Agron. 2011;56(4):373-376.
14. Reddy UVB, Reddy GP, Reddy NS, Kavitha P. Effect of different nitrogen and phosphorus levels on growth and yield of maize during kharif season. Int J Curr Microbiol Appl Sci. 2018;7(1):3548-3555.
15. Wang S, Cheng L, Zhang J, Liu W. Effects of boron deficiency and toxicity on maize growth and photosynthesis. Plant Physiol Biochem. 2019;135:326-334.
16. Lavelle P, Martin A. Small-scale and large-scale effects of endogeic earthworms on soil organic matter dynamics in soils of the humid tropics. Soil Biology and Biochemistry. 1992 Dec 1;24(12):1491-8.
17. Halder NK, Rafiuddin MD, Siddiky MA, Gomes R, Begam KA. Performance of Gladiolus as influenced by boron and zinc. Pakistan Journal of Biological Sciences: PJBS. 2007 Feb 1;10(4):581-5.