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Effect of boron application and nitrogen management on yield of maize (*Zea mays* L.)

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Abstract
A two-year field study was conducted at Mansarovar Global University, Sehore, M.P., during the Kharif seasons of 2023 and 2024 to evaluate the effect of Integrated Nitrogen Management (INM) combined with Boron application on maize (*Zea mays* L.) growth, yield, and grain quality. Fifteen treatments, comprising different combinations of nitrogen sources urea, Farmyard Manure (FYM), Vermicompost (VC), and Azotobacter with Boron at 2, 3, and 4 kg/ha, were arranged in a Randomized Block Design with three replications. Growth, cob characteristics, grain attributes, stover, and grain yield were recorded. The results revealed significant variation among treatments. Maximum cob girth (17.2 cm), rows per cob (16.15), test weight (235.15 g), stover yield (139.34 q/ha), and grain yield (69.5 q/ha) were observed under 100% N through urea with Boron @ 3 kg/ha. Partial substitution of urea with FYM, VC, or Azotobacter improved growth and yield moderately. Boron at 3 kg/ha consistently enhanced reproductive and yield parameters across treatments. The study demonstrates that integrated nitrogen management with Boron @ 3 kg/ha, either through full urea application or partial organic/biofertilizer substitution, is an effective strategy for maximizing maize productivity, improving grain quality, and promoting sustainable nutrient management.

Keywords: Maize (*Zea mays* L.), boron application, integrated nitrogen management, yield attributes, grain quality, sustainable nutrient management

Introduction
The scientific name *Zea mays* originates from two distinct linguistic sources. The term *Zea* is derived from ancient Greek, where it was used as a general reference to cereals and grains and is often interpreted as meaning "sustaining life." The word *mays* is taken from the Taino language, in which it means "life giver." Although the precise center of origin of maize (*Zea mays* L.) remains a matter of scholarly debate, researchers commonly attribute it either to the Andean regions of Peru, Bolivia, and Ecuador or to southern Mexico and Central America.
At present, maize is cultivated extensively across the globe, thriving under diverse agro-climatic conditions in countries such as 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 include Gujarat, Rajasthan, Punjab, Haryana, Bihar, Madhya Pradesh, Uttar Pradesh, Andhra Pradesh, Himachal Pradesh, and Jammu & Kashmir. Remarkably, attainable yields as high as 11-12 t ha^{-1} have been reported in Poland, reflecting the crop's exceptional genetic potential.
Agronomically, maize can be cultivated throughout the year due to its photo-thermo-insensitive nature, which enables it to adapt effectively to a wide range of environmental conditions. This adaptability has earned maize the title "Queen of Cereals." Owing to its high yield potential, maize is also referred to as a "miracle crop." As a C_4 plant, maize has a highly efficient photosynthetic mechanism that allows it to utilize solar radiation effectively for enhanced dry matter accumulation. However, because maize is a heavy feeder of nutrients, its productivity largely depends on appropriate and balanced nutrient management practices.
Sustaining soil fertility and ensuring efficient nutrient delivery are crucial for maintaining optimal crop productivity. In this context, Integrated Nutrient Management (INM) has emerged as a sustainable and scientifically sound strategy aimed at enhancing crop yield while preserving soil health. INM emphasizes the balanced and judicious use of both inorganic fertilizers and

organic sources such as farmyard manure (FYM), green manures, crop residues, and biofertilizers. This holistic approach ensures an adequate and continuous supply of nutrients, thereby improving nutrient-use efficiency and maintaining soil productivity in the long term.

Among the organic amendments, vermicompost has proven particularly beneficial for improving soil structure and fertility. It is produced through the interaction of microorganisms and earthworms under mesophilic conditions (up to 25°C). Vermicompost is a biologically stable product characterized by a low C:N ratio, high microbial and enzymatic activity, fine particulate structure, and excellent water-holding capacity. It supplies essential nutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) in readily available forms (Lavelle & Martin, 1992). Application of the recommended dose of fertilizers (RDF) in combination with FYM has been shown to improve maize germination, plant height, and overall growth (Shakoor *et al*., 2015) [11]. Similarly, higher levels of FYM have been reported to increase germination percentage and early plant vigor (Shahna & Sheikh).

Boron (B) is one of the most limiting micronutrients in agricultural soils, and its deficiency can significantly reduce the productivity of several crops, including cereals. Maize is particularly sensitive to micronutrient imbalances (Broadley *et al*., 2007) [5]. Boron plays a vital role in numerous physiological and biochemical processes such as cell division in meristematic tissues, carbohydrate metabolism and translocation, maintenance of membrane integrity, pollen tube growth, successful pollination, and seed formation (Siddiky *et al*., 2007) [16]. Adequate boron availability is therefore essential for reproductive success and grain development in maize. Globally, boron deficiency ranks as the second most widespread micronutrient constraint to soil fertility after zinc (Zn).

The combined management of macronutrients and micronutrients is essential to achieve higher productivity and quality in maize. Nitrogen, being a primary macronutrient, is the key driver of vegetative growth, chlorophyll synthesis, and yield formation. However, excessive or imbalanced application of nitrogen can lead to nutrient losses and reduced efficiency. Boron, on the other hand, enhances nitrogen uptake and utilization efficiency by supporting reproductive and metabolic processes. Hence, studying the interactive effects of nitrogen and boron is crucial to developing efficient and sustainable nutrient management strategies for maximizing yield and improving grain quality in maize.

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

Table 1.1: Effect of Integrated Nitrogen Management with Boron application on Cob girth of Maize.

Treatment	Treatment Combination	Cob Girth (cm)2023	Cob Girth (cm)2024	Cob Girth (cm) Average
T_1	100 % N through Urea + Boron@ 2 kg/ ha	14.3	14.3	14.3
T_2	100% N through Urea + Boron @ 3 kg/ ha	17	17.4	17.2
T_3	100% N through Urea + Boron@ 4 kg/ha	16.2	16.1	16.15
T_4	50% N through Urea + 50% N through FYM + Boron@ 2 kg/ ha	12.1	11.3	11.7
T_5	50 % N through Urea + 50% N through FYM + Boron@ 3 kg/ ha	15	15	15
T_6	50 % N through Urea + 50% N through FYM + Boron @ 4 kg/ ha	14.3	14.3	14.3
T_7	50 % N through Urea + 50% N through VC + Boron @ 2 kg/ ha	14.4	14.4	14.4
T_8	50 % N through Urea + 50 % N through VC + Boron@ 3 kg/ ha	14.9	14.2	14.55
T_9	50 % N through Urea + 50 % N through VC + Boron @ 4 kg/ ha	15.3	15.5	15.4
T_{10}	50 % N through Urea + 25 % N through FYM + 25% N through VC + Boron@ 2 kg/ha	14.4	14.4	14.4
T_{11}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron@ 3 kg/ha	13.9	13.9	13.9
T_{12}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron @ 4 kg/ha	14.4	14.6	14.5
T_{13}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron @ 2 kg/ha	14.5	14	14.25
T_{14}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron@ 3 kg/ha	15.4	15	15.2
T_{15}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron @ 4 kg/ha	13.8	13.8	13.8
	CD (5%)	1.58	1.7	1.64
	SE(m)	0.543	0.587	0.565

This table 1.1 presents the influence of various integrated nitrogen management treatments combined with different levels of boron on the cob girth (cm) of maize during the years 2023 and 2024, along with the average of both years. The treatments consisted of combinations of nitrogen sources Urea, Farmyard Manure (FYM), Vermicompost (VC), and Azotobacter applied with boron at rates of 2, 3, and 4 kg/ha.

The results revealed noticeable variation among treatments. The maximum average cob girth (17.2 cm) was recorded in T_2 (100% N through Urea + Boron @ 3 kg/ha), followed closely by T_3 (100% N through Urea + Boron @ 4 kg/ha) with 16.15 cm. Conversely, the lowest average cob girth (11.7 cm) was observed in T_4 (50% N through Urea + 50% N through FYM + Boron @ 2 kg/ha). Treatments incorporating integrated nitrogen sources (Urea, FYM, and VC) generally showed moderate cob girth compared to sole urea application.

Statistical analysis indicated that the differences among treatments were significant at the 5% level (CD = 1.64), with a standard error of the mean (SEm) = 0.565.

Overall, the findings suggest that applying 100% nitrogen through urea in combination with Boron @ 3 kg/ha was most effective in enhancing cob girth of maize under the given experimental conditions.

Table: 1.2: Effect of Integrated Nitrogen Management with Boron application on No. of Row per cob of Maize.

Treatment	Treatment Combination	No. of Row per cob 2023	No. of Row per cob 2024	No. of Row per cob Average
T_1	100 % N through Urea + Boron @ 2 kg/ha	14.5	14.4	14.45
T_2	100% N through Urea + Boron @ 3 kg/ ha	16.3	16	16.15
T_3	100% N through Urea + Boron @ 4 kg/ha	14.8	14.9	14.85
T_4	50% N through Urea + 50% N through FYM + Boron @ 2 kg/ha	14.5	14.5	14.5
T_5	50 % N through Urea + 50% N through FYM + Boron @ 3 kg/ ha	13.7	13.9	13.8
T_6	50 % N through Urea + 50% N through FYM + Boron @ 4 kg/ ha	14.3	14.3	14.3
T_7	50 % N through Urea + 50% N through VC + Boron @ 2 kg/ ha	13.1	13.6	13.35
T_8	50 % N through Urea + 50 % N through VC + Boron @ 3 kg/ ha	15	15.1	15.05
T_9	50 % N through Urea + 50 % N through VC + Boron @ 4 kg/ ha	15.1	15.1	15.1
T_{10}	50 % N through Urea + 25 % N through FYM + 25% N through VC + Boron @2 kg/ ha	14.6	14.5	14.55
T_{11}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron@ 3 kg/ ha	14	13.9	13.95
T_{12}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron @ 4 kg/ ha	15	15	15
T_{13}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron @ 2 kg /ha	14.5	15	14.75
T_{14}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron@ 3 kg/ ha	15.8	15.4	15.6
T_{15}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron @ 4 kg/ha	15	15.1	15.05
	CD (5%)	N/A	N/A	
	SE(m)	0.596	0.568	0.582

The data in Table 1.2 illustrate the influence of different nitrogen management practices in combination with varying levels of boron application on the number of rows per cob of maize during the 2023 and 2024 growing seasons. The results indicate a noticeable variation among the treatments.

The treatment T_2 (100% N through Urea + Boron @ 3 kg/ha) recorded the highest average number of rows per cob (16.15), followed closely by T_{14} (50% N through Urea + 25% N through FYM + 25% N through Azotobacter + Boron @ 3 kg/ha) with an average of 15.6. Treatments such as T_8 and T_{15} also performed comparably well with averages of 15.05 rows per cob. In contrast, the lowest number of rows per cob was observed under T_7 (50% N through Urea + 50% N through Vermicompost + Boron @ 2 kg/ha), which recorded an average of 13.35, indicating that both lower boron levels and organic nitrogen combinations may limit cob development.

Overall, treatments receiving moderate boron levels (3 kg/ha), especially in combination with either 100% urea nitrogen or partially substituted organic sources, tended to produce superior results. Statistical analysis revealed that the differences among treatments were not significant at the 5% level (CD - N/A), though notable trends were evident. The standard error (SEm) values ranged between 0.568 and 0.596, confirming consistency across both years.

Table 1.3: Effect of Integrated Nitrogen Management with Boron application on No. of Grains per row of Maize

Treatment	Treatment Combination	No. of Grains per row 2023	No. of Grains per row 2024	No. of Grains per row Average
T_1	100 % N through Urea + Boron @2 kg/ha	29.7	29.9	29.8
T_2	100% N through Urea + Boron@ 3 kg/ha	29.3	29.2	29.25
T_3	100% N through Urea + Boron @4 kg/ha	26.9	26.9	26.9
T_4	50% N through Urea + 50% N through FYM + Boron @ 2 kg/ ha	22.7	21.8	22.25
T_5	50 % N through Urea + 50% N through FYM + Boron @ 3 kg ha	27.4	27.3	27.35
T_6	50 % N through Urea + 50% N through FYM + Boron @ 4 /kg ha	28.5	28.6	28.55
T_7	50 % N through Urea + 50% N through VC + Boron@ 2 kg/ ha	25	24.1	24.55
T_8	50 % N through Urea + 50 % N through VC + Boron@ 3 kg/ ha	28.4	28.3	28.35
T_9	50 % N through Urea + 50 % N through VC + Boron @ 4 kg/ha	27.2	26.6	26.9
T_{10}	50 % N through Urea + 25 % N through FYM + 25% N through VC + Boron @ 2 kg/ ha	25.3	24.7	25
T_{11}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron @ 3 kg/ha	25	25	25
T_{12}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron@ 4 kg/ha	25.3	25.3	25.3
T_{13}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron@ 2 kg /ha	27.6	29.3	28.45
T_{14}	50 % through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron@ 3 kg/ ha	26.3	23	24.65
T_{15}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron @ 4 kg/ ha	26.9	27	26.95
	CD (5%)	N/A	4.232	4.232
	SE(m)	1.468	1.454	1.461

The data presented in the table 1.3 illustrate the influence of different nitrogen management strategies in combination with varying boron levels on the number of grains per row of maize during the years 2023 and 2024, along with their respective averages.

Across treatments, the number of grains per row exhibited notable variation depending on the nitrogen source and boron application rate. The results reveal that the treatment T_1 (100% N through Urea + Boron @ 2 kg/ha) recorded the highest average number of grains per row (29.8), followed closely by T_2 (100% N through Urea + Boron @ 3 kg/ha) with an average of 29.25 grains per row. Conversely, the lowest grain count (22.25) was observed under T_4 (50% N through Urea + 50% N through FYM + Boron @ 2 kg/ha), indicating reduced grain development under partial substitution of urea nitrogen with FYM at a lower boron dose.

Among the integrated nutrient management combinations, the treatment T_{13} (50% N through Urea + 25% N through FYM + 25% N through Azotobacter + Boron @ 2 kg/ha) also showed a relatively high performance (28.45 grains per row on average), suggesting a synergistic effect of biofertilizer and organic amendments with balanced nitrogen management. Treatments involving vermicompost (VC) exhibited moderate grain numbers, generally ranging from 24.55 to 28.35 grains per row.

The critical difference (CD) at 5% level was 4.232, and the standard error of mean (SEm) was approximately 1.46, indicating that the observed differences among treatments were statistically significant.

Table 1.4: Effect of Integrated Nitrogen Management with Boron application on test weight of Maize.

Treatment	Treatment Combination	Test weight (g) 2023	Test weight (g) 2024	Test weight (g) Average
T_1	100 % N through Urea + Boron @ 2 kg/ha	207.3	205.7	206.5
T_2	100% N through Urea + Boron@ 3 kg/ ha	236	234.3	235.15
T_3	100% N through Urea + Boron @ 4 kg/ ha	205.7	201	203.35
T_4	50% N through Urea + 50% N through FYM + Boron @2 kg/ha	198.7	186.7	192.7
T_5	50 % N through Urea + 50% N through FYM + Boron @ 3 kg/ha	230.3	224.7	227.5
T_6	50 % N through Urea + 50% N through FYM + Boron @ 4 kg/ha	206.3	212	209.15
T_7	50 % N through Urea + 50% N through VC + Boron @2 kg ha	210.7	209	209.85
T_8	50 % N through Urea + 50 % N through VC + Boron 3@ kg/ha	233.7	223.7	228.7
T_9	50 % N through Urea + 50 % N through VC + Boron @4 kg/ha	216.3	212.7	214.5
T_{10}	50 % N through Urea + 25 % N through FYM + 25% N through VC + Boron @ 2 kg/ ha	225.7	222.7	224.2
T_{11}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron @ 3 kg/ ha	229.7	223	226.35
T_{12}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron @ 4 kg/ ha	221.3	219	220.15
T_{13}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobacter* + Boron @ 2 kg /ha	224.3	218.7	221.5
T_{14}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobacter* + Boron@ 3 kg/ ha	234	231.3	232.65
T_{15}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobacter* + Boron @ 4 kg/ha	220.7	215	217.85
	CD (5 %)	2.909	10.184	6.5465
	SE(m)	0.999	3.497	2.248

This table 1.4 presents the influence of various nitrogen management strategies in combination with different levels of boron on the test weight of maize grains recorded during 2023 and 2024. The data reveal notable variations among the treatments, reflecting the synergistic effects of organic and inorganic nutrient sources on grain filling and kernel density.

Across both years, the highest average test weight (235.15 g) was observed under T_2 (100% N through Urea + Boron @ 3 kg/ha), followed closely by T_{14} (50% N through Urea + 25% N through FYM + 25% N through Azotobacter + Boron @ 3 kg/ha) with an average of 232.65 g, and T_8 (50% N through Urea + 50% N through Vermicompost + Boron @ 3 kg/ha) showing 228.7 g. These results indicate that the 3 kg/ha boron level consistently enhanced test weight irrespective of the nitrogen source, possibly due to improved translocation of assimilates and better grain development.

Conversely, the lowest test weight (192.7 g) was recorded under T_4 (50% N through Urea + 50% N through FYM + Boron @ 2 kg/ha), suggesting that lower boron rates or partial substitution of nitrogen solely with FYM may not suffice for optimal grain filling.

Statistical analysis revealed a significant difference among treatments, with a CD (5%) of 6.5465 and SE(m) of 2.248, confirming that the variations in test weight due to different nitrogen and boron management practices were meaningful.

Overall, the findings suggest that integrating balanced nitrogen management with boron application at 3 kg/ha, particularly when a portion of nitrogen is supplied through organic sources such as FYM, vermicompost, or Azotobacter, effectively enhances test weight and potentially improves maize grain quality.

The stover yield of maize varied significantly under different nitrogen management practices combined with boron application during the years 2023 and 2024. Treatments included 100% nitrogen through urea, partial substitution of urea with farmyard manure (FYM), vermicompost (VC), or Azotobacter inoculation, along with boron at 2, 3, and 4 kg/ha.

The highest average stover yield (139.34 q/ha) was observed in T_2 (100% N through Urea + Boron @ 3 kg/ha), followed by T_{14} (50% N through Urea + 25% N through FYM + 25% N through Azotobacter + Boron @ 3 kg/ha), which produced an average yield of 132.84 q/ha.

Table 1.5: Effect of Integrated Nitrogen Management with Boron application on Stover yield of Maize

Treatment	Treatment Combination	Stover yield q/ha 2023	Stover yield q/ha 2024	Stover yield q/ha Average
T	100 % N through Urea + Boron@ 2 kg/ ha	90	77.67	83.835
T_2	100% N through Urea + Boron@ 3 kg/ha	136.67	142	139.335
T_3	100% N through Urea + Boron @ 4 kg/ ha	106.67	98.67	102.67
T_4	50% N through Urea + 50% N through FYM + Boron @ 2 kg/ha	91.67	88.33	90
T_5	50 % N through Urea + 50% N through FYM + Boron @ 3 kg/a	116.67	114.33	115.5
T_6	50 % N through Urea + 50% N through FYM + Boron @ 4 kg/ha	106.67	93	99.835
T_7	50 % N through Urea + 50% N through VC + Boron @ 2 kg/ha	120	96.33	108.165
T_8	50 % N through Urea + 50 % N through VC + Boron @3 kg/ ha	106.67	104.33	105.5
T_9	50 % N through Urea + 50 % N through VC + Boron @ 4 kg/ha	108.3	97	102.65
T_{10}	50 % N through Urea + 25 % N through FYM + 25% N through VC + Boron @ 2 kg/ha	107.33	95	101.165
T_{11}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron @3 kg/ ha	106.67	99.33	103
T_{12}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron @ 4 kg/ha	106.67	90.33	98.5
T_{13}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron @2 kg /ha	106.67	97.67	102.17
T_{14}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron@ 3 kg/ha	136	129.67	132.835
T_{15}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron @ 4 kg/ ha	98.33	85.33	91.83
	CD (5%)	25.02	10.77	17.895
	SE(m)	8.678	7.851	8.2645

Treatments with partial substitution of nitrogen through FYM, VC, or Azotobacter generally showed moderate yields ranging from 99.83 to 115.5 q/ha. Lower stover yields were recorded in T_1 (100% N through Urea + Boron @ 2 kg/ha) and T_{15} (50% N through Urea + 25% N through FYM + 25% N through Azotobacter + Boron @ 4 kg/ha), with averages of 83.84 q/ha and 91.83 q/ha, respectively.

Statistical analysis indicated that the critical difference (CD) at 5% level was 17.895 q/ha, and the standard error of mean (SEm) was 8.2645 q/ha, confirming that the differences in stover yield among treatments were statistically significant.

In conclusion, 100% N through Urea with Boron @ 3 kg/ha produced the maximum stover yield, while integrated nitrogen management involving partial substitution with FYM or Azotobacter also enhanced stover production effectively. Boron application at 3 kg/ha was found to be optimal for achieving higher stover yields across different nitrogen management practices.

Table 1.6: Effect of Effects of Integrated Nitrogen Management with Boron application on grain yield of Maize.

Treatment	Treatment Combination	Grain Yield (q/ha) 2023		Grain Yield (q/ha) Average
T_1	100 % N through Urea + Boron @ 2 kg/ ha	38.07	39.33	38.7
T_2	100% N through Urea + Boron @ 3 kg/ ha	68.67	70.33	69.5
T_3	100% N through Urea + Boron @4 kg/ha	44.67	45.67	45.17
T_4	50% N through Urea + 50% N through FYM + Boron @ 2 kg/ ha	52.97	49.33	51.15
T_5	50 % N through Urea + 50% N through FYM + Boron @ 3 kg/ ha	55.4	56	55.7
T_6	50 % N through Urea + 50% N through FYM + Boron @ 4 kg ha	54.23	53.33	53.78
T_7	50 % N through Urea + 50% N through VC + Boron @ 2 kg/ ha	56.33	52.33	54.33
T_8	50 % N through Urea + 50 % N through VC + Boron @ 3 kg/ha	49.67	51.67	50.67
T_9	50 % N through Urea + 50 % N through VC + Boron @ 4 kg/ ha	49.03	49	49.015
T_{10}	50 % N through Urea + 25 % N through FYM + 25% N through VC + Boron @ 2 kg/ha	56.33	55.67	56
T_{11}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron @ 3 kg/ha	59.5	59.67	59.585
T_{12}	50 % N through Urea + 25 % N through FYM + 25 % N through VC + Boron @ 4 kg/ha	51.17	52.33	51.75
T_{13}	50 % N through Urea + 25 % N through FYM + 25 % Nthrough *Azotobactor* + Boron @ 2 kg ha	57.5	59.67	58.585
T_{14}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron@ 3 kg/ ha	65.67	66	65.835
T_{15}	50 % N through Urea + 25 % N through FYM + 25 % N through *Azotobactor* + Boron @ 4 kg/ ha	57.7	54	55.85
	CD (5%)	6.954	4.478	5.716
	SE(m)	3.595	2.90 6	3.595

The table 1.6 illustrates the effect of different nitrogen management strategies combined with boron application on the grain yield (q/ha) of maize over two years (2023 and 2024), along with the average yield. Fifteen treatments were evaluated, varying in nitrogen sources urea, farmyard manure (FYM), vermicompost (VC), and Azotobacter inoculation and boron levels (2, 3, and 4 kg/ha).

Among the treatments receiving 100% nitrogen through urea, T_2 (Boron @ 3 kg/ha) recorded the highest average grain yield of 69.5 q/ha, followed by T_3 (45.17 q/ha) and T_1 (38.7 q/ha). Treatments combining urea with FYM (T_4-T_6) resulted in moderate yields, with T_5 producing the highest average of 55.7 q/ha. Similarly, combinations of urea with VC (T_7-T_9) produced average yields ranging from 49.02 to 54.33 q/ha, while split applications of urea, FYM, and VC (T_{10}-T_{12}) improved yield further, the highest being 59.585 q/ha (T_{11}). Treatments incorporating Azotobacter inoculation (T_{13}-T_{15}) recorded substantial yields, with T_{14} (Boron @ 3 kg/ha) achieving 65.835 q/ha.

The differences among treatments were statistically significant at the 5% level, with a Critical Difference (CD 5%) of 5.716 q/ha and SEm of 3.595 q/ha. Overall, the results indicate that integrated nitrogen management, particularly when combined with Boron at 3 kg/ha and biofertilizer application, substantially enhances maize grain yield.

Conclusion

The study on the effect of Integrated Nitrogen Management (INM) with Boron application on maize (*Zea mays* L.) revealed significant variations in growth, yield, and quality parameters across different treatments. Application of 100% nitrogen through urea combined with Boron @ 3 kg/ha consistently produced superior results, recording the highest values for cob girth (17.2 cm), number of rows per cob (16.15), test weight (235.15 g), stover yield (139.34 q/ha), and grain yield (69.5 q/ha).

Partial substitution of urea with organic sources such as Farmyard Manure (FYM), Vermicompost (VC), or biofertilizer (Azotobacter) also improved growth and yield parameters, though generally to a moderate extent compared to full urea application. Among the Boron levels tested, 3 kg/ha was found to be optimal for enhancing cob development, grain formation, kernel density, and overall yield.

Overall, the findings suggest that integrated nitrogen management with Boron @ 3 kg/ha, particularly through full urea application or partial organic/biofertilizer substitution, is effective in improving maize growth, productivity, and grain quality under the experimental conditions. This approach can serve as a practical recommendation for maximizing maize yield while promoting sustainable nutrient management.

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