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EVALUATING THE ROLE OF INTEGRATED NUTRIENT MANAGEMENT IN ENHANCING COB CHARACTERISTICS AND PRODUCTIVITY OF MAIZE (*ZEA MAYS* L.)

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ABSTRACT

A field experiment was carried out to investigate the influence of integrated nitrogen management and boron application on the cob characteristics and yield of maize (*Zea mays* L.). The experimental layout followed a Randomized Block Design (RBD) with 15 treatment combinations replicated three times. Treatments consisted of various combinations of nitrogen sourced from urea, farmyard manure (FYM), vermicompost (VC), Azotobacter and boron. Among the treatments, T_2 (100% nitrogen through urea + boron @ 3 kg ha^{-1}) achieved the highest values for cob length (24.2 cm in 2018, 24.3 cm in 2019, and 24.2 cm pooled), cob girth (16.6 cm in 2018, 17.4 cm in 2019, and 17.0 cm pooled) and test weight (236 g in 2018, 231 g in 2019 and 234.3 g pooled). This was closely followed by T_{14} (50% nitrogen through urea + 25% nitrogen through FYM + 25% nitrogen through Azotobacter + boron @ 3 kg ha^{-1}), which also showed significant improvement in these parameters. While cob length and girth responded significantly to nitrogen and boron levels, the number of rows per cob remained unaffected. Boron application positively influenced the number of grains per row and test weight, with T_2 producing the highest number of grains per row (29.6 in 2018 and 29.2 in 2019) and the heaviest test weight and grain yield (68.67 q/ha and 71.67 q/ha). In contrast, the lowest values for these parameters were observed in T_4 (50% nitrogen through urea + 50% nitrogen through FYM + boron @ 2 kg ha^{-1}). The findings highlight the importance of integrated nutrient management strategies, particularly the combination of nitrogen and boron, in enhancing maize productivity.

Key words : Cob characteristics, INM, Yield, Organic manures, Inorganic fertilizer.

Introduction

The increasing global demand for food, coupled with limited per capita arable land, presents a significant challenge to sustainable agriculture. Maize (*Zea mays* L.), a critical cereal crop, ranks third in global production after wheat and rice and is cultivated extensively across tropical, subtropical and temperate zones. In developing countries, maize demand is projected to Surpass that of wheat and rice by 2020 (Broadley *et al.*, 2007). This versatile crop is grown on nearly 184 million hectares across 125 countries and serves as a primary food source, animal feed, and industrial raw material (Mahesh *et al.*, 2010). Factors such as hybrid genetic potential, soil properties, agronomic practices and climatic conditions collectively influence maize grain yield (Humtsoe *et al.*, 2018). Biological nitrogen-fixing bacteria, such as Azotobacter and Azospirillum, play a crucial role in enhancing crop productivity. These free-living bacteria fix atmospheric nitrogen, boosting grain yields in crops like maize, wheat and potatoes by 10–18% (Mahto and Neupane, 2017). Additionally, they contribute to improved plant biomass and grain quality, fixing 20–40 kg of nitrogen per hectare annually (Masih *et al.*, 2018). Beyond nitrogen fixation, Azotobacter species produce antifungal compounds that protect plants from diseases (Mahto and Neupane, 2017).

Organic amendments like vermicompost, which result from the decomposition of organic matter by earthworms and microorganisms, have gained prominence in sustainable agriculture. Vermicompost is rich in nutrients (N, P, K, Ca, Mg) in plant-available forms, has a low C:N ratio, and exhibits high microbial activity, moisture retention, and fine particle structure (Mohsin *et al.*, 2012; Singh *et al.*, 2011). Combining recommended doses of fertilizers (RDF) with organic inputs such as farmyard manure (FYM) enhances seed germination and plant height in maize (Naseb *et al.*, 2015; Singh *et al.*, 2017). The positive impact of FYM on crop growth is well-documented, with increased application rates correlating to higher germination percentages (Omar, 2014). Micronutrient deficiencies, particularly boron, significantly affect crop productivity. Boron, essential for meristematic cell division, carbohydrate metabolism, pollen tube development and seed formation, is the second most limiting micronutrient after zinc in Indian soils (Ramaswami *et al.*, 2011; Sujatha *et al.*, 2008). Boron deficiency leads to physiological and structural impairments in plants, while excessive levels, particularly under drought conditions, can cause toxicity and yield loss (Verma *et al.*, 2018a; Verma *et al*., 2018b). Boron's availability in soil is influenced by environmental factors, necessitating precise nutrient management to prevent imbalances. Soil health deterioration due to excessive chemical fertilizer use and intensive cropping has resulted in nutrient imbalances and toxicity, underscoring the need for integrated nutrient management (INM). INM combines chemical fertilizers, organic amendments, and biological fertilizers to optimize nutrient supply, enhance soil physico-chemical properties, and ensure long-term sustainability. Biological fertilizers like Azotobacter, Azospirillum, blue-green algae, Azolla, phosphorus-solubilizing microorganisms, mycorrhizae, and Rhizobium provide eco-friendly alternatives to chemical fertilizers (Masih *et al.*, 2018). Research highlights the widespread deficiency of macro- and micronutrients in Indian soils, particularly nitrogen, causing symptoms such as leaf yellowing, firing of lower leaves, and stunted growth.

Materials and Methods

Experimental Site

The experiment was conducted during the Zaid season of 2018 and 2019 at the Department of Agronomy, SHUATS, Prayagraj. The experimental field forms part of the Central Gangetic alluvial plain, characterized by deep, neutral soils. The study was designed using a Randomized Block Design (RBD) with 15 treatments, each replicated three times. Treatment T_1 consisted of 100% N applied through urea with boron at 2 kg ha^{-1}. Treatment T_2 involved 100% N through urea with boron at 3 kg ha^{-1}, while T_3 included 100% N through urea with boron at 4 kg ha^{-1}. Treatment T_4 was a combination of 50% N through urea and 50% N through FYM (farmyard manure) with boron at 2 kg ha^{-1}, whereas T_5 and T_6 followed similar combinations with boron applied at 3 kg ha^{-1} and 4 kg ha^{-1}, respectively. Treatment T_7 used 50% N through urea and 50% N through VC (vermicompost) with boron at 2 kg ha^{-1}, followed by T_8 and T_9, which included the same combination with boron at 3 kg ha^{-1} and 4 kg ha^{-1}, respectively. Treatment T_{10} comprised 50% N through urea, 25% N through FYM, and 25% N through VC, with boron at 2 kg ha^{-1}. Similarly, T_{11} and T_{12} had the same combination with boron at 3 kg ha^{-1} and 4 kg ha^{-1}, respectively. Treatment T_{13} involved 50% N through urea, 25% N through FYM, and 25% N through Azotobacter with boron at 2 kg ha^{-1}, while T_{14} and T_{15} had the same combination with boron at 3 kg ha^{-1} and 4 kg ha^{-1}, respectively. The nutrient sources included Urea, Single Super Phosphate (SSP), Muriate of Potash (MOP), FYM, Vermicompost, Azotobacter and Boron. The recommended dose of nitrogen (RDN) was 150 kg N ha^{-1}, along with 80 kg P_2O_5 ha^{-1}, 60 kg K_2O ha^{-1} and 2, 3, or 4 kg Boron ha^{-1}, depending on the treatment. Phosphorus, Potassium and Boron were applied as a basal dose at the time of sowing, while Urea (Nitrogen) was split into three applications. Data collected during the experiment were compiled and processed using MS Excel and analysed statistically with OPSTAT software, used to draw inferences, and the standard error of the mean and critical difference (CD) at a 5% probability level were calculated to compare treatment means.

Results and Discussion

An appraisal of the Table 1 and Fig. 1 clearly reveals that application of Nitrogen and Boron significantly increased the length of cob at harvest during 2018 and 2019 in Zaid season. The maximum length of cob (24.2 cm, 24.3 cm and 24.2cm) was recorded in the year 2018. 2019 and in pooled in the treatment combination T_2- (100% N through urea+ Boron @ 3 kg.ha^{-1}) respectively followed by treatment combination T_{14} - (50% N through urea + 25% N through FYM+25% N through *Azotobactor* + Boron @ 3 kg.ha^{-1}) year 2018, 2019 and in pooled and recorded cob length to a tune of 22.8 cm, 22.5 cm and 22.6 cm, respectively. On further review of the table-4.17, it was found that in the year 2018 treatment combination T_{14} - (50% N through urea + 25% N through FYM+25% N through *Azotobactor* + Boron @ 3 kg.ha^{-1}) was statistically at par to treatment combination T2-(100% N through urea+ Boron 3 kg,ha^{-1}) but not in 2019 as well as in pooled. The probable reason for significant effect of these factors under study may be ascribed to

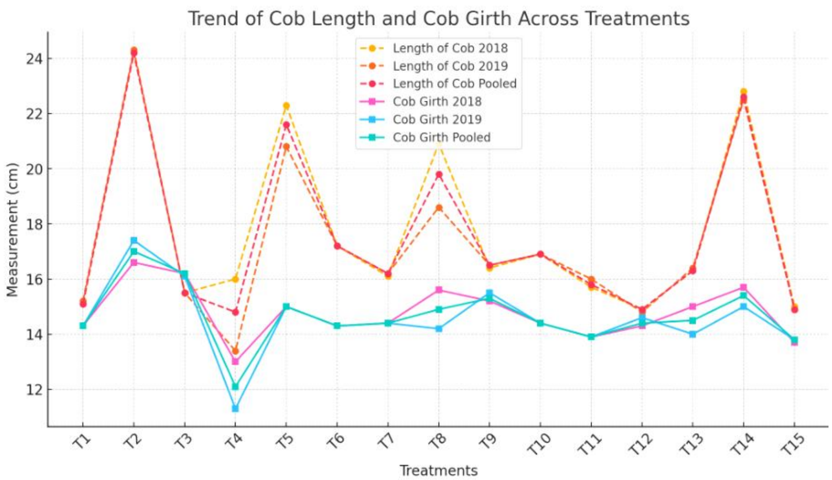

Fig. 1 : Effect of Integrated Nitrogen Management with Boron application on cob length(cm) of maize.

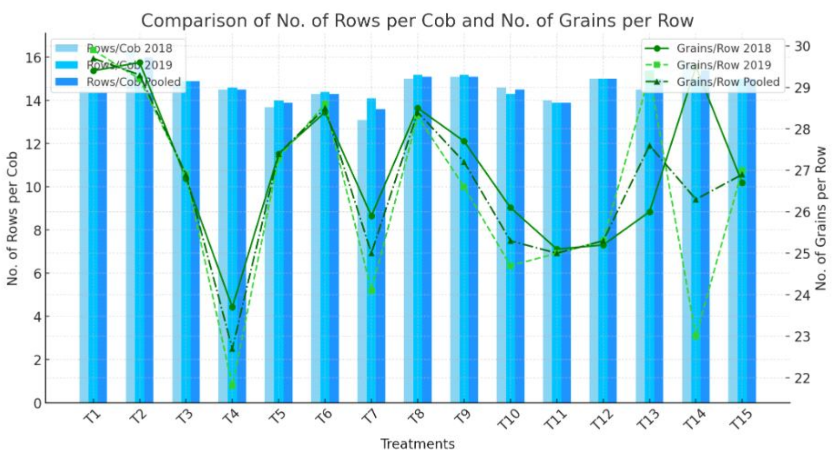

Fig. 2 : Effect of Integrated Nitrogen Management with boron application on no. of row per cob of maize.

genetic characteristics of the variety. Yield attributes and yield of a crop is a function of several components which are dependent on complementary interaction between vegetative and reproductive growth of the crop. The maximum length of cob was recorded in which all the yield attributing characters were performing at their best potential. The cob girth differed significantly with different treatment combination of integrated Nitrogen management with Boron application. Significantly maximum cob girth of maize crop at harvest (16.6 cm, 17.4cm and 17.0 cm) was recorded in the treatment combination T_2- (100% N through urea+ Boron @ 3 kg.ha^{-1}) in the year 2019 and closely followed by treatment combination T_3, T_{14}, T_8, T_{13}, T_9 and T_5, which were found to be statistically at par to treatment combination T_2- (100% N through urea+ Boron 3 kg,ha^{-1}), respectively. In the year 2019 and in pooled significantly maximum cob girth (17.4 cm and 17.0 cm) was recorded in the treatment combination T_2- (100% N through urea+ Boron 3 kg.ha^{-1}) followed by treatment combination T_3- (100% N through urea + Boron @ 4 kg.ha^{-1}) and was found to be statistically at par to the treatment combination T_2- (100% N through urea+ Boron 3@ kg.ha^{-1}). The probable reason for significant effect on cob girth may be ascribed to genetic characteristics of the variety. Yield attributes and yield of a crop is a function of several components which are dependent on complementary interaction between vegetative and reproductive growth of the crop. The maximum cob girth was recorded in which all the yield attributing characters were performing at their best potential. The other reason may be due to better utilization of nutrients, moisture and solar radiation and higher dose of nitrogen which imparts green colour to leaves of plant and better photosynthesis led to maximum length of cob. Similar findings were also reported by Samsul *et al.* (2012), Singh *et al.* (2017) and Zaremanesh *et al.* (2017).

A critical review of the Table 2 and Fig. 2 reveals that effect of integrated nitrogen management with boron application was found to have non-significant effect on number of rows per cob. However, non-significantly maximum grain rows (16.3, 15.7 and 16) was recorded by the treatment combination T_2- (100% N through urea+ Boron @ 3 kg/ha^{-1}) in both the years of experimental trial as well as in pooled followed by treatment combination T_{14} - (50% N through urea + 25% N through FYM+25% N through *Azotobactor* + Boron @ 3 kg.ha^{-1}), which recorded number of rows as 15.8, 15.0 and 15.4 in 2018, 2019 and in pooled, respectively. Effect of integrated nitrogen management with boron application was found to have non-significant effect on number of grains per row in the year 2018 and in pooled but reveals significant effect in the year 2019. However, non-significantly maximum number of grains/ rows (29.60, 29.20 and 29.30) was recorded by the treatment combination T_2- (100% N through urea + Boron @ 3 kg/ha^{-1}) in both the years of experimental trial as well as in pooled. In the year 2019 significantly maximum number of grains/row (29.90) was recorded in treatment combination T1- (100 % N through Urea + Boron @ 2 kg ha^{-1}) followed by treatment combination T_2, T_{13}, T_6, T_8, T_5, T_{15}, T_3, T_9 and were statistically at par to treatment combination T_1- (100% N through Urea +

Table 1 : Effect of Integrated Nitrogen Management with Boron application on cob length(cm) of Maize.

Treatment	Length of cob (cm) 2018	Length of cob (cm) 2019	Length of Pooled cob (cm)	Cob Girth (cm)2018	Cob Girth (cm)2019	Cob Girth (cm) Pooled
T_1	15.1	15.2	15.1	14.3	14.3	14.3
T_2	24.2	24.3	24.2	16.6	17.4	17.0
T_3	15.5	15.5	15.5	16.2	16.1	16.2
T_4	16.0	13.4	14.8	13.0	11.3	12.1
T_5	22.3	20.8	21.6	15.0	15.0	15.0
T_6	17.2	17.2	17.2	14.3	14.3	14.3
T_7	16.1	16.2	16.2	14.4	14.4	14.4
T_8	20.9	18.6	19.8	15.6	14.2	14.9
T_9	16.4	16.5	16.5	15.2	15.5	15.3
T_{10}	16.9	16.9	16.9	14.4	14.4	14.4
T_{11}	15.7	16.0	15.8	13.9	13.9	13.9
T_{12}	14.9	14.8	14.9	14.3	14.6	14.4
T_{13}	16.3	16.4	16.3	15.0	14.0	14.5
T_{14}	22.8	22.5	22.6	15.7	15.0	15.4
T_{15}	15.0	14.9	14.9	13.7	13.8	13.8
C.D	1.427	1.503	1.409	1.93	1.70	1.58
C.V	4.801	5.176	4.793	7.787	6.986	6.411

Table 2 : Effect of Integrated Nitrogen Management with Boron application on No. of Row per cob of Maize.

Treatment	No. of row per cob 2018	No. of Row per cob 2019	No. of Row per cob Pooled	No. of grains per row 2018	No. of grains per row 2019	No. of grains per row Pooled
T_1	14.5	14.4	14.4	29.4	29.9	29.7
T_2	16.3	15.7	16.0	29.6	29.2	29.3
T_3	14.8	14.9	14.9	26.8	26.9	26.9
T_4	14.5	14.6	14.5	23.7	21.8	22.7
T_5	13.7	14.0	13.9	27.4	27.3	27.4
T_6	14.3	14.4	14.3	28.4	28.6	28.5
T_7	13.1	14.1	13.6	25.9	24.1	25.0
T_8	15.0	15.2	15.1	28.5	28.3	28.4
T_9	15.1	15.2	15.1	27.7	26.6	27.2
T_{10}	14.6	14.3	14.5	26.1	24.7	25.3
T_{11}	14.0	13.9	13.9	25.1	25.0	25.0
T_{12}	15.0	15.0	15.0	25.2	25.3	25.3
T_{13}	14.5	15.4	15.0	26.0	29.3	27.6
T_{14}	15.8	15.0	15.4	29.5	23.0	26.3
T_{15}	15.0	15.0	15.0	26.7	27.0	26.9
C.D	N/A	N/A	N/A	N/A	4.232	N/A
C.V	7.027	7.405	6.689	11.094	9.512	9.499

Boron @ 2 kg ha^{-1}) respectively. The probable reason for non- significant effect on number of rows/cob and number of grains per row may be ascribed to genetic characteristics of the variety and being the same variety in all treatment combination not much difference was observed among different treatment combination. These results are in line with those reported by Ravi *et al*. (2012) and Verma *et al.* (2018)

Data in Table 3 and Fig. 3 reveals that test weight differed significantly with different treatment combination of integrated Nitrogen management with Boron application. Significantly maximum test weight (236.00 g) of maize crop at harvest was recorded in treatment combination T_2- (100% N through urea+ Boron @ 3 kg,ha$^-$

Table 3 : Effect of Integrated Nitrogen Management with Boron application on test weight and grain yield (q/ha) of Maize.

Treatment	Test weight (g) 2018	Test weight (g) 2019	Test weight (g) Pooled	Grain Yield (q/ha) 2018	Grain Yield (q/ha) 2019	Grain Yield (q/ha) Pooled
T_1	207.3	201.7	205.7	38.07	40.33	39.33
T_2	236.0	231.0	234.3	68.67	71.67	70.33
T_3	205.7	200.7	201.0	44.67	46.17	45.67
T_4	198.7	191.7	186.7	52.97	45.50	49.33
T_5	230.3	221.3	224.7	55.40	56.50	56.00
T_6	206.3	197.0	212.0	54.23	52.17	53.33
T_7	210.7	205.0	209.0	56.33	47.83	52.33
T_8	233.7	227.7	223.7	49.67	53.55	51.67
T_9	216.3	206.0	212.7	49.03	48.83	49.00
T_{10}	225.7	217.0	222.7	56.33	55.33	55.67
T_{11}	229.7	219.3	223.0	59.50	59.83	59.67
T_{12}	221.3	212.3	219.0	51.17	53.33	52.33
T_{13}	224.3	217.0	218.7	57.50	61.17	59.67
T_{14}	234.0	223.3	231.3	65.67	65.67	66.00
T_{15}	220.7	214.7	215.0	57.70	50.67	54.00
C.D	2.909	4.409	10.184	6.954	6.312	4.478
C.V	0.786	1.235	2.805	7.595	6.966	4.906

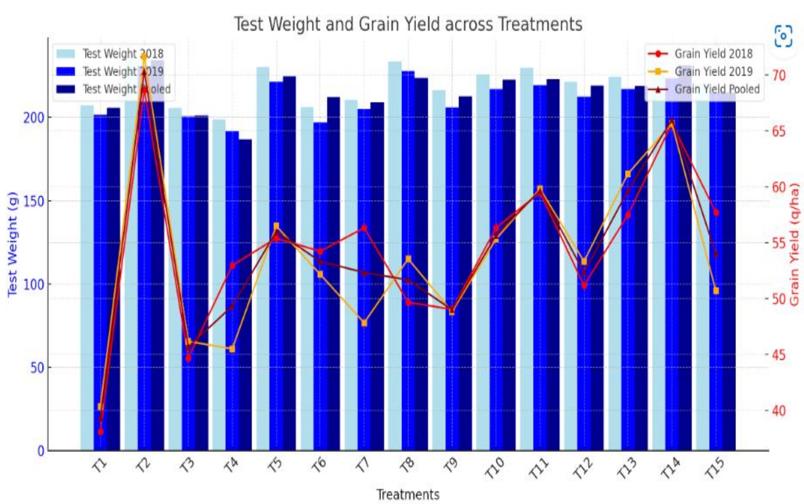

Fig. 3 : Effect of Integrated Nitrogen Management with Boron application on test weight and grain yield (q/ha) of Maize.

^{1}) followed by treatment combination T_{14}- (50 % N through Urea + 25 % N through FYM + 25% N through *Azotobacter* + Boron @ 3 kg ha^{-1}) and treatment combination T_8- (50 % N through Urea + 50 % N through VC + Boron @ 3 kg ha^{-1}), which were found to be statistically at par to treatment combination T_2- (100% N through urea+ Boron @ 3 kg,ha^{-1}), respectively. In the year 2019 significantly maximum test weight (231.0 g) was registered in treatment combination T_2- (100% N through urea+ Boron @ 3 kg.ha^{-1}) and followed by treatment combination T_8- (50 % N through Urea + 50% N through VC + Boron @ 3 kg ha^{-1}) which was found to be statistically at par to treatment combination T_2- (100% N through urea+ Boron @ 3 kg,ha^{-1}). Similarly in pooled, maximum test weight (234.30 g) was recorded in treatment combination T_2- (100% N through urea + Boron @ 3 kg.ha^{-1}) followed by treatment combination T_8- (50% N through Urea + 50% N through VC + Boron @ 3 kg ha^{-1}) and was found to be statistically at par to treatment combination T_2- (100% N through urea+ Boron @ 3 kg.ha^{-1}). significantly maximum grain yield (68.67 q/ha, 71.67 q/ha and 70.33q/ha) was recorded in treatment combination T_2- (100% N through urea + Boron @ 3 kg/ha) in the year 2018, 2019 and in pooled respectively and followed by treatment combination T_{14}- (50% N through urea + 25% N through FYM + 25% N through *Azotobacter* @ 3 kg.ha^{-1}). On further review of the Table 3, it was observed that treatment T_{14}- (50% N through urea + 25% N through FYM + 25% N through *Azotobacter* @ 3 kg.ha^{-1}) was statistically at par to treatment combination T_2- (100% N through urea + Boron @ 3 kg/ha) and recorded grain yield to a tune of 65.67 q/ha in the year 2018. In the year 2019 and in pooled also treatment combination T_{14}- (50% N through urea + 25% N through FYM + 25% N through *Azotobacter* @ 3 kg.ha^{-1}) was found to be statistically at par to treatment combination T_2 – (100% N through urea + Boron @ 3 kg/ha). The plausible reason for maximum yield in the treatments mentioned above may be attributed to uptake more nutrients, moisture throughout the vegetative and reproductive phase and greater availability of nitrogen which led to productive movement from source to sink leading to higher grain yield. These findings are in accordance with those reported by Prasad *et al.* (2003), Dwivedi *et al.* (2014) and Verma *et al.* (2018).

Conclusion

The present study demonstrated the significant impact of integrated nitrogen management and boron application on the growth and yield attributes of maize (*Zea mays* L.). Among the 15 treatment combinations, T_2 (100% nitrogen through urea + boron @ 3 kg ha^{-1}) consistently exhibited superior performance in terms of cob length, cob girth, test weight and the number of grains per row and grain yield across both years (2018 and 2019) and in pooled data. T_{14} (50% nitrogen through urea + 25% nitrogen through FYM + 25% nitrogen through Azotobacter + boron @ 3 kg ha^{-1} also showed notable improvements, ranking second in these parameters. The findings also suggest that nitrogen and boron, applied in optimal proportions, play a critical role in enhancing cob characteristics and grain quality. However, the number of rows per cob was not significantly influenced, likely due to the genetic stability of the maize variety used. Treatments with lower nitrogen levels or reduced boron application, such as T_4 (50% nitrogen through urea + 50% nitrogen through FYM + boron @ 2 kg ha^{-1}), recorded the lowest performance for key parameters.

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