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Influence of zinc and boron on growth and yield of maize

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Abstract
A field experiment was conducted during *kharif* season of 2023 at Crop Research Farm, Department of Agronomy, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj (U.P.). The experiment was laid out in a Randomized Block Design with 10 treatments and replicated thrice. The treatment consisted of 3 levels of Zinc (15, 20 and 25 kg/ha as soil application) and 3 levels of Boron (0.5%, 0.75% and 1% as foliar application) along with basal application of recommended doses of fertilizer and a control (120:60:60 kg N-P-K/ha). The results revealed that application of Zinc 25 Kg/ha + Boron 1% (treatment 9) recorded maximum plant height (219.13 cm), dry weight (169.57 g), number of grain rows per cob (17.20), number of grains per row (31.27), grain weight per cob (90.05 g), grain yield (7.82 t/ha) and straw yield (16.37 t/ha). The same treatment also recorded maximum B:C ratio (2.43) in Maize.

Keywords: Boron, economics, maize and zinc

Introduction
Maize is one of the most versatile crops having wider adaptability under diverse soil and climatic condition. Globally, maize is known as the "Queen of cereals'' because it has the highest genetic yield potential amongst cereals. Maize is utilized for food (25%), animal feed (12%), poultry feed (45%), starch (12%), brewery (1%) and seed (1%). Maize grains are very good source of starch (75%), protein (10%), fibre (8.5%), oil (4.8%), sugar (3%) and ash (1.7%) with significant quantities of vitamin A, nicotinic acid and vitamin E (Hussain *et al.*, 2022) [7]. It is cultivated in an area of about 203.22 million hectares with a production of 1223.81 million metric tonnes and an average productivity of 6.02 metric tonnes per hectares. The major maize production countries are USA, China, Brazil, European Union, Argentina, India, Ukraine, Mexico, Russia and Canada. In India, maize is cultivated in an area of about 11.00 million hectares with a production of 37.50 million metric tonnes and an average productivity of 3.41 metric tonnes per hectares (United States Department of Agriculture 2024) [23].

Boron (B) is an essential element required for normal plant growth and development of all plants (Brown *et al.*, 2008) [2]. Due to its importance as a structural element of the cell wall, it is regularly required for plants throughout their life (Wimmer and Eichert 2013) [25]. Boron deficiency may cause many anatomical, biochemical, and physiological changes in crops. It is important for cell wall and cytokinin formation, cell division, sugar metabolism and transportation, indole acetic acid (IAA) and ribose nucleic acid metabolism, seed germination and formation (Kaur and Nelson 2015) [9]. B helps to maintain the integrity of plant cell membranes, which increases the ability of membranes to transport essential nutrients, different B treatments had a substantial impact on micronutrient uptake (Nazir *et al.*, 2019) [13].

Zinc (Zn) is an essential element for normal growth and development in plants as it plays vital role in enzyme activation and also involved in the biosynthesis of some enzymes and growth hormone. Zinc application has been proved beneficial in improving crop yield and quality (Hassan *et al.*, 2019) [6], while its deficiency reduces yield and deteriorates crop quality (Mousavi *et al.*, 2007) [12]. In Indian soils, zinc deficiency is a major problem. Soil pH, lime content, organic matter amount, clay type and amount and the amount of applied phosphorus fertilizer affect the available Zn concentration in soil (Adiloglu and Adiloglu, 2006) [1].

Materials and Methods

The experiment was carried out during *kharif* season of Crop research Farm, SHUATS, Prayagraj, Uttar Pradesh. The soil of experimental plot was sandy loam in texture, high in organic carbon (0.830%), neutral in soil Ph (7.0), medium in available Nitrogen (290.5 kg/ha), high in available Phosphorous (36.7 kg/ha) and medium in available Potassium (253.2 kg/ha). The experiment was laid out in a Randomized Block Design with 10 treatments and replicated thrice. The treatment consisted of 3 levels of Zinc (15, 20 and 25 kg/ha as soil application) and 3 levels of Boron (0.5%, 0.75% and 1% as foliar application at 20 and 45 DAS) along with basal application of recommended doses of fertilizer and a control (120:60:60 N-P-K kg/ha). The treatment combinations are T_1 - Zinc 15 kg/ha + Boron 0.5%, T_2 - Zinc 20 kg/ha + Boron 0.5%, T_3 - Zinc 25 kg/ha + Boron 0.5%, T_4 - Zinc 15 kg/ha + Boron 0.75%, T_5 - Zinc 20 kg/ha + Boron 0.75%, T_6 - Zinc 25 kg/ha + Boron 0.75%, T_7 - Zinc 15 kg/ha + Boron 1%, T_8 - Zinc 20 kg/ha + Boron 1%, T_9 - Zinc 25 kg/ha + Boron 1% and T10 – Control (120:60:60 N-P-K kg/ha). Plant growth attributes *viz*., plant height (cm) and dry weight (g) were recorded at 20, 40, 60 and 80 DAS interval and Yield attributes *viz*., number of grain rows/cob, number of grains/rows, grain weight/cob (g), grain yield (t/ha) and straw yield (t/ha) were recorded at harvest. The data were recorded and statistically analysed by analysis of variance method (ANOVA) as applicable to randomized block design by Gomez and Gomez (1984). The results were presented at 5% level of significance (p=0.05) to make comparisons between the treatments.

Results and Discussion

Growth attributes

Observations of growth attributes *viz.,* plant height and plant dry weight has been presented in Table 1.

Plant height

The plant height increases gradually with the progress of the crop towards maturity and attained maximum growth at harvest. At 80 DAS, significantly higher plant height (219.13 cm) was recorded with application of 25 kg/ha Zinc (Soil application) and foliar application of 1% Boron (treatment 9), while treatment 5 and treatment 8 were found statistically at par with the highest. The increased in plant height might be due to the specific combination of zinc and boron along with the application of recommended dose of fertilizer applied. Zinc helps in improving the uptake of nutrients significantly in maize. Also, zinc plays a crucial role in various metabolic processes including photosynthesis, hormone regulation and enzyme activation which in turn acts as a stimulator of growth. Furthermore, zinc helps in improving the resistance of maize plant to stress providing better growth. Boron plays an important role in development of roots, sugar transport and metabolism. Boron is also crucial for cell wall formation and hormone regulation which helps in cell division, cell elongation and expansion. This synergy results in the balance and continuous supply of nutrients, promoting growth. Similar findings were also reported by Parasuraman *et al.* (2008) [14], Manasa & Devaranavadagi (2015) [11] and Deswal *et al.* (2018) [4] which stated that levels of zinc significantly affect the plant height with maximum under highest level of zinc application. Boron helps in better assimilation of nitrogen and both these elements interact positively with each other and help in improving the growth parameters of the plants (Shaaban *et al.* 2004) [18]. Increase in plant growth attributes with boron application was also reported by Soomro *et al.* (2011) [22] and Shabbir *et al.* (2020) [19] in maize.

Plant dry weight

The plant dry weight gradually increased with the advancement of crop age and reached maximum at harvest. At 80 DAS, significantly higher plant dry weight (169.57 g) was recorded with the application of 25 kg/ha Zinc (Soil application) and foliar application of 1% Boron (treatment 9), while T_6 (168.09 g), T_7 (163.36 g) and T_8 (165.29 g) were found to be statistically at par with the highest. This might be due to the combination of zinc and boron along with the recommended dose of fertilizers which creates a synergistic effect as zinc and boron help in maximizing the efficiency of metabolic processes, nutrient uptake and stress tolerance, leading to enhanced biomass production and higher dry weight. Balancing their availability in the soil is essential to maximize the growth and quality. Potarzycki *et al.* (2015) [17] also reported similar types of finding and stated that higher biomass was obtained with application of zinc during vegetative phase of the crop. Wasaya *et al.* (2017) [24] also reported a significant increase in plant height, chlorophyll content, leaf area index and all dry weight fractions with the application of amendment containing boron in maize. Similar results in maize were also obtained by Phonglosa *et al.* (2019) [16].

Yield attributes

The observation related to yield attributing parameters *viz.,* number of grain rows/cob, number of grains/rows and grain weight/cob (g) were shown in Table 1. Significant and maximum number of grain rows per cob (17.20), maximum number of grains per rows (31.27) and highest grain weight per cob (90.05 g) was recorded with the application of 25 kg/ha Zinc (Soil application) and foliar application of 1% Boron (Treatment 9). The increased in the above given yield attributes might be due to synergistic effects of zinc and boron to enhance reproductive development, influence pollen viability, hormone balance, nutrient uptake and metabolic processes essential for reproductive growth. Zinc and boron help in development of healthy maize plants capable of producing a higher number of cobs. Chand *et al.* (2017) [3] and Kafle *et al.* (2022) [8] also reported similar findings and stated that with application of zinc and boron obtained higher yield attributes in maize.

Grain yield

The observations recorded for grain yield is presented in Table 1. Significant and maximum grain yield (7.82 t/ha) was recorded with the application of 25 kg/ha Zinc (Soil application) and foliar application of 1% Boron (treatment 9). However, T6 (7.11 t/ha), T7 (6.99 t/ha) and T8 (7.04 t/ha) were found to be statistically at par with the highest. The increased in grain yield might be due to the role of zinc and boron in improving the allometric traits, chlorophyll, relative water content, nutrient uptake and increase in yield components. Maize is responsive to water contents and nutrients with high nutrient requirement at all growth stages and with their adequate supply, results in higher grain yield. Wasaya *et al.* (2017) [24] and Singh *et al.* (2017) [21] also reported similar findings stating that there is a significant increase in grain yield with the application of zinc and boron in maize.

Straw yield

The observations recorded for straw yield is presented in Table 1. Significant and maximum straw yield (16.37 t/ha) was recorded with the application of 25 kg/ha Zinc (Soil application) and foliar application of 1% Boron (Treatment 9). However, T3 (14.84 t/ha), T6 (15.59 t/ha), T7 (14.76 t/ha) and T8 (14.80 t/ha)

were found to be statistically at par with the highest. The increased in straw yield might be due to the synergetic combination of zinc and boron. Zinc and boron play a role in promoting photosynthesis, protein synthesis and carbohydrate metabolism which are crucial for biomass accumulation. Also, zinc and boron help in stress tolerance which helps the plant to grow without stress which in-turn help in developing taller and thicker plants, increased chlorophyll and overall growth of the plants which increases number of green leaves, higher leaf area, diameter of stem which results in higher straw yield in maize. Shubhangi *et al.* (2022) [20] and Kumar *et al.* (2019) [10] also reported similar findings and stated that application of zinc and boron helps in increasing the straw yield in maize significantly.

Economics

The data pertaining to economics namely B:C ratio is presented in Table 1. The data showed that maximum B:C (2.43) ratio was recorded with the application of 25 kg/ha Zinc (soil application) and foliar application of 1% Boron (treatment 9).

Table 1: Effect of Zinc and Boron on growth and yield of maize

S. No.	Treatments	Plant Height (cm)	Plant Dry Weight (g)	Grain rows/cob	Grains/rows	Grain weight/cob	Grain Yield	Straw Yield	B:C ratio
		80 DAS		(No.)	(No.)	(g)	(t/ha)	(t/ha)	
1.	Zinc 15 kg/ha + Boron 0.5%	198.33	144.63	14.13	27.67	76.89	5.88	13.61	1.75
2.	Zinc 20 kg/ha + Boron 0.5%	204.27	153.97	15.06	28.20	76.77	6.30	13.77	1.85
3.	Zinc 25 kg/ha + Boron 0.5%	203.40	149.48	14.40	27.66	79.98	6.71	14.84	1.99
4.	Zinc 15 kg/ha + Boron 0.75%	205.00	157.04	15.33	28.46	77.67	5.52	12.14	1.54
5.	Zinc 20 kg/ha + Boron 0.75%	211.40	154.96	16.00	27.00	81.60	6.19	13.70	1.81
6.	Zinc 25 kg/ha + Boron 0.75%	207.53	168.09	15.20	29.13	83.77	7.11	15.59	2.16
7.	Zinc 15 kg/ha + Boron 1%	210.47	163.36	16.13	27.73	88.64	6.99	14.76	2.19
8.	Zinc 20 kg/ha + Boron 1%	211.27	165.29	16.93	30.13	89.91	7.04	14.80	2.15
9.	Zinc 25 kg/ha + Boron 1%	219.13	169.57	17.20	31.27	90.05	7.82	16.37	2.43
10.	Control: 120:60:60 N-P-K kg/ha	202.47	143.33	14.00	26.80	78.35	4.93	10.86	1.41
	SEm (±)	2.751	3.804	0.457	0.654	9.562	0.357	0.740	-
	CD (P=0.05)	8.172	11.30	1.36	1.94	3.21	1.06	2.19	-

Conclusion

From the present experiment, it is concluded that the application of 25 kg/ha Zinc (soil application) and 1% Boron (foliar application) along with recommended doses of fertilizer recorded the highest yield and B:C ratio in *kharif* maize.

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