Original Research Article

EFFECT OF BORON, ZINC AND IRON ON GROWTH AND YIELD OF SUMMER MAIZE

Abstract

The field experiment was conducted during *Zaid* 2022 at Crop Research Farm, Department of Agronomy,SHUATS, Prayagraj (U.P). The soil of experimental plot was sandy loam in texture, nearly neutral in soilreaction (pH 6.9), available N (278.93 kg/ha), available P (10.8 kg/ha) andavailableK(206.4kg/ha).TheexperimentwaslaidoutinRandomizedBlockDesignwith9treatmentseach replicated thrice on the basis of one year experimentation.The resultsshowed that applicationofBoron 0.6%+ Zinc 25kg/ha + Iron 25kg/ha in treatment no. 8 was recordedsignificantlymaximumplantheight(205.79cm),Plantdryweight(179067 g/plant),Crop growthrate(28.11g/m^2/day)No.ofleaves/plant(13.93),No.ofcob/plant(2.07), No. of row/cob (14.67), No. of seeds/row (26.00),Testweight(238.0 g), Grain yield (5.40 t/ha), Straw yield (9.60 t/ha), Harvest index (35.97), Gross returns (122400.0 INR/ha), Net return (77210.0 INR/ha) andbenefitcost ratio (1.71)as compared to other treatments.

Key word:-Boron ,Zinc, Iron Growth, Yield

Introduction

After rice and wheat, maize (*Zea mays* L.) is one of the most significant cereal crops and plays a significant role in world agriculture. In India, it comes in third behind rice and wheat. It is produced in India for grain, for human consumption, as a component of poultry and cow feed, as well as for other industrial uses. One of the most important and strategically important crops in the world is maize, commonly known as maize. Mexico is where it first appeared. (Central America). Due to its significant role in the diets of humans and animals as well as its high yielding capacity, it is known as the "queen of cereals." It is known as a "Miracle Crop" because it effectively uses solar energy and has a tremendous potential for better output. The provision of food is greatly aided by maize.**(Dragana *et al.* 2015).**

Additionally, boron is not translocated to new growth and is quite static in plants, although it is very mobile in soil**.Sinha et al. (2009)**Although boron decreased the concentration of starch, protein in seeds and storage organs, ascorbic acid in tomato fruits, and oil in oil seeds, the economic yield was decreased and the product's quality degraded. Boric acid, which directly improves a number of plant development features, can be applied topically to address deficits. **(Zhang, 2009; Ahmad *et al.* 2012) [23, 2].**

One of the most crucial micronutrients for the growth of numerous agricultural plants, including the widely grown rice, maize, and wheat, is zinc. Scientists are well aware that zinc has an impact on a variety of mechanisms that control the life cycles of plants. Enzymatic activity, auxin production, carbohydrate metabolism, and protein synthesis are a few metabolic activities that are critical for plant growth and, consequently, for the effective regulation of nitrogen metabolism. Additionally, zinc activity effectively regulates a variety of physiological processes, such as pathogen pressure, heat, or drought, which increases growing plants' resilience to biotic and abiotic challenges.**(Grzebisz *et al.*, 2008).**

Additionally, iron is a necessary component of many proteins and enzymes that are present during respiration and photosynthesis. Since iron is immobile in plants and its mobility declines with soil pH, an excess of phosphorus may result in a deficiency. Iron deficiency in crops, especially those grown on calcareous soils, is a serious nutritional condition that stunts vegetative growth and results in significant yield and quality losses.**(Abadia et al. 2011).**

2. MATERIALS AND METHODS

A field experiment was conducted during Zaid season 2022 at Crop Research Farm, Department of Agronomy, Naini Agriculture Institute, Sam Higginbotton University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh.The experiment laid out in Randomized Block Design which consist of nine treatment combinations and three replications. The treatments details are T_1: 0.3% Boron + 20 kg/ha Zinc + 20 kg/ha Iron, T_2: 0.3% Boron + 20 kg/ha Zinc + 25 kg/ha Iron, T_3: 0.3% Boron + 25 kg/ha Zinc + 20 kg/ha Iron, T_4: 0.3% Boron + 25 kg/ha Zinc + 25 kg/ha Iron, T_5: 0.6% Boron + 20 kg/ha Zinc + 20 kg/ha Iron, T_6: 0.6% Boron + 20 kg/ha Zinc + 25 kg/ha Iron, T_7: 0.6% Boron + 25 kg/ha Zinc + 20 kg/ha Iron, T_8: 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron, T_9: Control R.D.F(N.P.K 120:60:60).The results were documented for a several growth characteristics, including plant height, No. of leaves/plant, plant dry weight and yield parameters like No. of cobs/plant, No. of row/cob, No. of grains/row, test weight, grain yield, stover yield and harvest index.

3. RESULTS AND DISCUSSION

3.1 Growth Attributes

3.1.1 Plant height

At 100 DAS, treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron was recorded maximum plant height (205.79 cm), which are significantly superior over all the treatments, However it was followed by the treatment with application of 0.6% Boron + 25 kg/ha Zinc + 20 kg/ha Iron, 0.6% Boron + 20 kg/ha Zinc + 25 kg/ha Iron and 0.6% Boron + 20 kg/ha Zinc + 20 kg/ha Iron (201.28, 194.56 and 189.61) and there was significant difference among other treatments.

The plant height of maize was observed to be significantly increasing throughout all crop growth stages. This could be explained by the integrated use of the micronutrient zinc, which resulted in adequate and balanced nutrient supply to the crop at the right time and place. This promoted rapid vegetative growth, which produced more internodes and leaves, thereby increasing the plant height. The findings and the results are very similar**Kumar *et al*. (2019).**

3.1.2 Numbers of leaves/plant

At 100 DAS, treatment with the application of 06% Boron + 25 kg/ha Zinc + 25 kg/ha Iron through micronutrients was recorded maximum number of leaves per plant (13.94), which was significantly superior over all the treatments. However, treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 20 kg/ha Iron and 0.6% Boron + 20 kg/ha Zinc + 25 kg /ha Iron (13.72 and 13.13) was statistically at par with treatment 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron through micronutrients.

The longer availability of plant nutrients was the cause of the increased number of leaves per plant at all growth stages. The micronutrient zinc's synergistic effects ensure that the plant receives enough nutrients throughout the growing season. The individual plants could have produced more leaves by efficiently ~~utilising~~utilizing the resources available for plant growth. The application of micronutrients also resulted in an increase in the number of leaves per plant, as was amply demonstrated by**Chandrasekar *et al*. (2000).**

3.1.3 Plant dry weight (g/plant)

At 100 DAS, treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron was recorded higher plant dry weight (179.67 g), which was significantly superior over all the treatments and there was statistical difference among application of 0.6% Boron + 25 kg/ha Zinc + 20 kg/ha Iron and 0.6% Boron + 20 kg/ha Zinc + 25 kg/ha Iron other treatment combinations.

The application of plant nutrients in conjunction with organic and inorganic substances made plant nutrients available throughout the growth season, increased plant height, the number of leaves per plant, and total leaf area, and ultimately enhanced the production of dry matter. The increase in leaf count may have improved the efficiency of maize's photosynthetic process and led to the production of more plant dry matter. This was consistent with the earlier results of **Barbara *et al*. (2018), Latha *et al*. (2011) and Ravichandra (2015).**

3.2 Yield Attributes and Yield

3.2.1 Number of cobs/plant

Treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron through Inorganic fertilizers was recorded maximum number of cobs per plant (2.07), which was significantly superior over all the treatments. However, treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 20 kg/ha Iron and 0.6% Boron + 20 kg/ha Zinc + 25 kg/ha Iron through Inorganic fertilizers (1.97 and 1.92) and control plot receiving recommended dose of fertilizers (1.09) were statistically at par with treatment 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron.

A large amount of biomass was eventually accrued, and a large portion of assimilates were partitioned to the sink thanks to the application of nutrient sources in combination with foliar applications of zinc and boron. This resulted in improved yield structures (cobs), as demonstrated by all of the yield ~~attributes.The~~attributes. The finding of **Nadeem *et al*. (2014)** confirmed these results.

3.2.2 No. of row/cob

Treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron was recorded maximum number of row per cob (14.67), which are significantly superior over all the treatments. However the treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 20 kg/ha Iron and 0.6% Boron + 20 kg/ha Zinc + 25 kg/ha Iron (14.33 and 13.67) was statistically at par with treatment 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron.

Utilizing plant nutrients from both organic and inorganic sources wisely has a positive impact on physiological The growth and yield processes then improve yield characteristics like the number of grains per row of maize. Similar outcomes were obtained by**Varalakshmi*etal*.(2005).**

3.2.3 Number of seeds/row

Treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron was recorded maximum number of seeds per row (26.00), which are significantly superior over all the treatments. However treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 20 kg/ha Iron and 0.6% Boron + 20 kg/ha Zinc + 25 kg/ha Iron (24.00 and 23.33) was statistically at par with treatment 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron.

Integrated nutrition supply consistently improved yield parameters. (**Raikar *et al.,* 2009**).Due to earlier absorption of macro- and micronutrients and their larger concentration, photosynthesis is better distributed to reproductive parts, resulting in enhanced growth and yield qualities. **Prakash *et al*. (2018)** also reported similar findings.

3.3 Test weight (g)

The test weight of maize (238.00) was recorded significantly higher the application of 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron. However the treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 20 kg/ha Iron and 0.6% Boron + 20 kg/ha Zinc + 25 kg/ha Iron had recorded (233.33 and 229.67) which were found significantly at par with treatment 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron.

The simulated effect of the combined administration of micronutrient ~~fertilisers~~fertilizers and zinc on cell proliferation and expansion is what causes the increase in cob length and girth. (**Mohsin *et al.* 2008**). The balanced supply of nutrients from micronutrients in combination with inorganic ~~fertilisers~~fertilizers during the grain filling and development stage is primarily responsible for the increase in 1000 grain weight. (**Manasa *et al.* 2015**).

3.4 Grain yield (t/ha)

Treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron was recorded higher grain yield (5.40 t/ha), which was significantly superior over all the treatments combinations.

Micronutrients are superior because they can supply nutrients in soluble form for a quiet longer time by preventing the entire soluble form from solution from coming into contact with soil and other inorganic constituents, which ~~minimises~~minimizes fixation and precipitation. Additionally, plant roots can effectively compete with loss mechanisms and absorb more nutrients, which results in better yield. Similar results were obtained by (**Moghazy *et al.* 2014**).

3.5 Stover yield (t/ha)

Treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron was recorded higher stover yield (9.60 t/ha), which was significantly superior over all the treatments. However, treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 20 kg/ha Iron (9.45 t/ha), 0.6% Boron + 20 kg/ha Zinc + 25 kg/ha Iron (9.09 t/ha) and 0.6% Boron + 20 kg/ha Zinc + 20 kg/ha Iron (8.65 t/ha) were statistically at par with treatment 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron.

3.6 Harvest index (%)

Treatment with the application of 0.6% Boron 25 kg/ha Zinc + 25 kg/ha Iron was recorded higher harvest index (35.97%), which was significantly superior over all the treatments. However, treatment with the application of 0.6% Boron + 25 kg/ha Zinc + 20 kg/ha Iron (35.38%), 0.6% Boron + 20 kg/ha Zinc + 25 kg/ha Iron (34.95%) and 0.6% Boron + 20 kg/ha Zinc + 20 kg/ha Iron (34.44%) were statistically at par with treatment 0.6% Boron + 25 kg/ha Zinc + 25 kg/ha Iron.

As a result of applying nutrients in combination, adequate biomass production, improved nutrient uptake, and improved yield metrics have led to increased yield. For maize to function well, the soil must be enriched with N and P in a form that is easily available. (**Tariq *et al.* 2014**).

Boron (B), zinc (Zn), and iron (Fe) are essential micronutrients for plant growth and development. Their deficiency can negatively affect crop productivity, including summer maize, a widely cultivated crop in tropical zones of Latin America (Hernandez et al. 2018a).

B is essential for the development of cell walls, cell division, and fruit development. Studies have shown that B deficiency can result in poor root development, reduced leaf expansion, and poor pollen germination, leading to reduced yield in summer maize (Olivares and Hernandez, 2020). Similarly, Zn is required for several enzymatic reactions and plays a crucial role in photosynthesis and protein synthesis. Zn deficiency can lead to chlorosis, stunted growth, and reduced grain yield in summer maize (Olivares et al. 2020). Fe is an essential component of chlorophyll, which is required for photosynthesis. Fe deficiency can lead to interveinal chlorosis, reduced growth, and yield in summer maize.

Soil studies in tropical zones of Latin America have shown that soils are often deficient in micronutrients such as B, Zn, and Fe, leading to reduced crop productivity (Calero et al. 2022). These studies have identified several factors contributing to micronutrient deficiency, including soil pH, organic matter content, and soil texture (Olivares, 2016; 2022). Moreover, these studies have also highlighted the importance of soil management practices such as fertilizer application, crop rotation, and irrigation in improving soil fertility and micronutrient availability (Hernandez and Olivares, 2019; Hernandez et al. 2020).

Comparing the findings of these soil studies with the effect of B, Zn, and Fe on the growth and yield of summer maize, it becomes evident that the deficiency of these micronutrients can negatively affect crop productivity in tropical zones of Latin America (Rey et al. 2022; Vega et al. 2022; Lobo et al. 2023). To address this challenge, it is necessary to adopt soil management practices that improve soil fertility and micronutrient availability, such as applying micronutrient-rich fertilizers, implementing crop rotation, and irrigation practices (Hernández et al. 2017; Olivares, 2018; Hernandez et al. 2018b; Arias et al. 2018;Orlando and Lopez, 2019).

In conclusion, B, Zn, and Fe are essential micronutrients for the growth and development of summer maize. Their deficiency can negatively affect crop productivity, leading to reduced yield. Soil studies in tropical zones of Latin America have shown that soil micronutrient deficiency is a common challenge that can be addressed by adopting soil management practices (Rodriguez et al. 2015; Olivares et al. 2018; López et al. 2019). By comparing these findings, it becomes evident that improving soil fertility and micronutrient availability is crucial for enhancing summer maize productivity in tropical zones of Latin America.

4. CONCLUSION

Based on the findings of the investigation it can be concluded that the foliar application of boron 0.6% and 25 kg/ha zinc along with 25 kg/ha iron (Treatment 8) was found to be more productive (5.40 t/ha) and commercially viable (1.71).

Table 1. Influence of Boron, Zinc and Iron on Growth and Growth Attributes of Maize

S. No.	Treatments	Plant height (cm)	Leaves/plant	Plant dry weight (g/Plant)
1.	0.3% Boron + 20kg/ha. Zinc + 20kg/ha. Iron	172.88	12.42	161.27
2.	0.3% Boron + 20kg/ha. Zinc + 25kg/ha. Iron	175.18	12.69	162.07
3.	0.3% Boron + 25kg/ha. Zinc + 20kg/ha. Iron	178.73	12.79	164.53
4.	0.3% Boron + 25kg/ha. Zinc + 25kg/ha. Iron	183.69	12.89	166.50
5.	0.6% Boron + 20kg/ha. Zinc + 20kg/ha. Iron	189.69	12.90	169.37
6.	0.6% Boron + 20kg/ha. Zinc + 25kg/ha. Iron	194.56	13.13	171.60
7.	0.6% Boron + 25kg/ha. Zinc + 20kg/ha. Iron	201.28	13.72	176.27
8.	0.6% Boron + 25kg/ha. Zinc + 25kg/ha. Iron	205.79	13.93	179.67
9.	120:60:60 kg/ha NPK (Control)	167.34	9.59	160.57
	F Test	S	S	S
	SEm (±)	6.96	0.5747	5.012
	CD (P=0.05)	20.89	1.72	15.03

Table 2. Influence of Boron, Zinc and Iron on yield and yield attributes of maize.

S. No.	Treatments	Cobs/Plant	Rows/Cob	Grains/row	Test weight (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
1.	0.3% Boron + 20kg/ha. Zinc + 20kg/ha. Iron	1.18	12.20	21.33	207.87	4.01	8.38	32.14
2.	0.3% Boron + 20kg/ha. Zinc + 25kg/ha. Iron	1.31	13.00	21.67	211.13	4.13	8.49	32.67
3.	0.3% Boron + 25kg/ha. Zinc + 20kg/ha. Iron	1.48	12.97	22.33	216.83	4.22	8.66	32.82
4.	0.3% Boron + 25kg/ha. Zinc + 25kg/ha. Iron	1.71	13.33	22.67	221.83	4.42	8.73	32.62
5.	0.6% Boron + 20kg/ha. Zinc + 20kg/ha. Iron	1.82	12.67	23.00	225.00	4.70	8.95	34.44
6.	0.6% Boron + 20kg/ha. Zinc + 25kg/ha. Iron	1.92	13.67	23.33	229.67	4.90	9.09	34.95
7.	0.6% Boron + 25kg/ha. Zinc + 20kg/ha. Iron	1.97	14.33	24.00	233.33	5.20	9.45	35.38
8.	0.6% Boron + 25kg/ha. Zinc + 25kg/ha. Iron	2.07	14.67	26.00	238.00	5.40	9.60	35.97
9.	120:60:60 kg/ha NPK (Control)	1.09	12.03	20.33	207.03	3.92	8.52	31.90
	F Test	S	S	S	S	S	S	S
	SEm (±)	0.13	0.46	0.81	6.71	0.19	0.25	0.79
	CD (P=0.05)	0.40	1.40	2.45	20.12	0.58	0.77	2.37

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