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Influence of Sulfur and Zinc on Growth and Yield of *Rabi* Maize (*Zea mays* L.)

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ABSTRACT

A field experiment was carried out at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (UP) India, during the *rabi* season of 2022-2023. To study the response of sulfur (20,30,40 kg/ha) and zinc (15,20,25 kg/ha). The experiment was laid out in Randomized Block Design with 9 treatments replicated thrice. Results showed that the plant height (164.2 cm), dry weight (165.8 g/plant), Crop growth rate (15.9 g/m^2/day), number of cobs per plant (2.33), number of grains per cob (533.8), grain yield (6.42 t/ha) and stover yield (14.36 t/ha) were recorded in treatment 9 with the application of Sulfur 40 kg/ha + Zinc 25 kg/ha. Higher gross returns (INR 1,30,264.40/ha), higher net returns (INR 90,007.65/ha) and maximum B:C ratio (2.23) were also recorded in treatment-9 (Sulfur 40 kg/ha + Zinc 25 kg/ha).

Keywords Maize, Sulfur, Zinc, Growth parameters, Yield attributes.

INTRODUCTION

Maize (*Zea mays* L.) is the most important alternative for crop diversification in most of Indian states to replace some area from rice (*Oryza sativa* L.) to conserve much needed ground water and improve soil health. Maize is one of the important cereal crops in the world's agricultural economy both as food for human consumption and feed for animal. For sustainable agriculture diverse crop production with its wider adaptability, higher yielding ability and fast growing habit as a potential alternative is important. Ariraman *et al*. (2020) across the world, it is cultivated on about 201 million hectares, with a yield of 5754.7 kilograms per hectare and a production of 1162 million tons (FAOSTAT 2020). In the year 2020-2021, India produced 31.51 million tons across an area of 9.9 million hectares. In India, maize is mostly grown in rainy (*Kharif*) and cold (*rabi*) seasons. In India, *kharif* maize represents around 83 % of the total area planted with the crop, while *rabi* Maize accounts for 17%. With the prevalence of numerous biotic and abiotic stresses, more than 70% of *kharif* maize acreage is farmed in a rainfed environment. *Rabi* maize (4436 kg/ha), which is mostly grown under specified ecosystem condition, has higher productivity than *kharif* maize (2706 kg/ha), which is grown in stress- prone

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ecology. The productivity of maize is low in India as compared to the world's productivity. Therefore, an attempt has been made to increase the production potential of maize.

Sulfur is a secondary essential nutrient for many growth functions in plants including nitrogen metabolism, protein and oil synthesis (Jeet *et al*. 2012). Sulfur is used in the production of S- containing materials. Amino acids namely cystene, cysteine and methionine, and various enzymatic processes resulting in higher meristematic activities and apical growth, result in the plant's overall growth (Chaudhary *et al*. 2013). When sulfur is deficient in the soil, the full yield potential of the crop cannot be achieved regardless of other nutrients even under good crop management practices.

Zinc influences the activities of hydrogenase and carbonic anhydrase, which plays a crucial role in plant metabolism and the stabilization of ribosomal proteins. Amongst crops, maize shows a high sensitivity to zinc deficiency for its physiological requirements. Through the regulation of auxin synthesis, maintenance of cell membrane integrity, protein synthesis and glucose metabolism, zinc stimulates plant enzymes. It is essential for the synthesis of auxin because zinc helps in tryptophan production, which is a precursor of Indole- 3-acetic acid (IAA). Balanced fertilization is the key to achieving higher productivity and nutrient use efficiency (Singh *et al*. 2015).

Keeping these points in view, the present investigation titled "Effect of Sulfur and Zinc on Growth and Yield of *Rabi* Maize (*Zea mays* L.)" was conducted during *rabi* 2022-23, at Crop Research Farm, SHUATS, Prayagraj (UP).

MATERIALS AND METHODS

At the Crop Research Farm, Department of Agronomy, Sam Higginbottom University of Agriculture Technology and Sciences (SHUATS), Prayagraj (UP) India, a field experiment was carried out during the *rabi* season of 2022-2023. The soil in the experimental plot was sandy loamy in texture, nearly neutral in soil reaction (pH 7.8), low in organic carbon (0.35%). The treatments consist of Sulfur 20 kg/ha + zinc 15 kg/ha, Sulfur 20 kg/ha + Zinc 20 kg/ha, Sulfur 20 kg/ha + Zinc 25 kg/ha, Sulfur 30 kg/ha + zinc 15 kg/ha, Sulfur 30 kg/ha + Zinc 20 kg/ha, Sulfur 30 kg/ha + Zinc 25 kg/ha, Sulfur 40 kg/ha + Zinc 15 kg/ha, Sulfur 40 kg/ha + Zinc 20 kg/ha, Sulfur 40 kg/ha + Zinc 25 kg/ha. The experiment was laid out in Randomized Block Design, with 9 treatments replicated thrice.

The observations were recorded for plant height (cm), plant dry weight (g/plant), crop growth rate ($g/m^2/day$), relative growth rate (g/g/day), number of cobs/plant, number of grains/cob, seed index (g), grain yield (t/ha) and stover yield (t/ha). The data were subjected to statistical analysis by analysis of variance method (Gomez and Gomez 1976).

RESULTS AND DISCUSSION

Growth parameters

Plant height (cm)- At 100 DAS, the significantly higher plant height (164.2 cm) (Table-1) was observed in treatment-9 (Sulfur 40 kg/ha + Zinc 25 kg/ha). However, treatment-6 (Sulfur 30 kg/ha +Zinc 25 kg/ha) and treatment-8 (Sulfur 40 kg/ha + Zinc 20 kg/ha) was found to be statistically at par with treatment- 9 (Sulfur 40 kg/ha + Zinc 25 kg/ha). The significantly higher plant height was observed with the application of Sulfur 40 kg/ha. This increase may be due to involvement of sulfur in bio synthesis of Indole 3 acetic acid and also, sulfur plays an important role in growth and development of crops. It owing an important role in the formation of S- containing amino acids like cystine (27% S), Cysteine (26% S), Methionine (21% S), which act as building blocks in the synthesis of proteins. Similar results find out by Chouhan *et al*. (2017). Further increase of plant height is might be due to application of Zinc 25 kg/ha, due to the role of zinc as a "catalyst" in most physiological, metabolic, and tryptophane synthesis processes. Certain protein elements are required to produce growth hormones (auxins) including IAA. There were similar findings described by Singh (2009).

Plant dry weight(g) - At 100 DAS, the significantly higher plant dry weight (165.8 g) (Table-1) was observed in treatment-9 (Sulfur 40 kg/ha + Zinc 25 kg/

Table 1. Effect of sulfur and zinc on growth of *rabi* maize.

Sl. No.	Treatment combinations	Plant height (cm)	Dry weight (g/plant)	Crop growth rate (g/m²/day)
1	Sulfur 20 kg/ha +Zinc 15 kg/ha	153.5	158.8	15.1
2	Sulfur 20 kg/ha +Zinc 20 kg/ha	154.2	159.3	15.2
3	Sulfur 20 kg/ha +Zinc 25 kg/ha	155.3	161.9	15.6
4	Sulfur 30 kg/ha +Zinc 15 kg/ha	154.8	160.4	15.5
5	Sulfur 30 kg/ha +Zinc 20 kg/ha	157.7	162.3	15.7
6	Sulfur 30 kg/ha +Zinc 25 kg/ha	158.3	163.9	15.7
7	Sulfur 40 kg/ha +Zinc 15 kg/ha	155.1	160.7	15.8
8	Sulfur 40 kg/ha +Zinc 20 kg/ha	163.4	164.3	15.8
9	Sulfur 40 kg/ha +Zinc 25 kg/ha	164.2	165.8	15.9
	F test	S	S	S
	SEm (±)	2.26	0.61	0.15
	CD (p=0.05)	6.80	1.86	0.45

ha). However, treatment-6 (Sulfur 30 kg/ha +Zinc 25 kg/ha) treatment-8 (Sulfur 40 kg/ha + Zinc 20 kg/ha) was found to be statistically at par with treatment- 9 (Sulfur 40 kg/ha + Zinc 25 kg/ha). The significantly higher plant dry weight (165.8 g) was observed with the application of Sulfur 40 kg/ha. It has a role in increasing chlorophyll formation and aiding photosynthesis. Sulfur plays a role in the activation of enzymes nucleic acids and forms parts of biotin and thiamine. Further increase in the dry weight might be due to the application of Zinc at 25 kg/ha. Zinc is essential for promoting certain metabolic reactions. It is necessary for the production of chlorophyll and carbohydrates. Zinc helps to activate the synthesis of tryptophan and precursor of lAA which is responsible to stimulation of plant growth and accumulation of biomass. These results are in findings with Monu *et al*. (2019).

Crop growth rate (g/m²/day) - At 60-80 DAS, the significantly higher crop growth rate (15.9 g/m²/day) (Table-1) was observed in treatment-9 (Sulfur 40 kg/ha + Zinc 25 kg/ha). However, treatment- 1 (Sulfur 20 kg//ha + Zinc 15 kg/ha) was observed with lowest crop growth rate. The significantly higher crop growth rate was observed with the Sulfur application 40 kg/ha. It could be increase in chlorophyll contents, maximum number of leaves and dry matter accumulation/plant and resulted activation of different physiological processes. Due to foliar application of micronutrients which increased the production of dry matter, stomatal regulation, chlorophyll formation, enzyme activation and biochemical activities occurred. So, the CGR were significantly increased.

Yield attributes

Number of cobs per plant

Significantly higher no. of cobs per plant (2.33) was observed in treatment-9 with application of (40 kg/ha sulfur + 25 kg/ha zinc). However treatment-5 with application of (30 kg/ha sulfur + 20 kg/ha zinc), treatment-6 (30 kg/ha sulfur + 25 kg/ha zinc) and treatment-8 (40 kg/ha sulfur + 20 kg/ha zinc) were found to be statistically at par with treatment-9 (40 kg/ha sulfur + 25 kg/ha zinc).

The experimental data indicated that, the yield attributing characters like number of cob/plant, length of cob, number of grains/cob, seed index(g), grain yield (q/ha), stover yield (q/ha), biological yield (q/ha) and harvest index (%) showed positive corelation with yield. Ali *et al*. (2013) found that application of sulfur at 25 and 35 kg/ha gave significant increase in no. of days of tasseling and silking. Kumar *et al.* (2018) observed that the application of increasing doses of Zn increases the yields of maize cob.

Number of grains per cob

Significant effect was observed by the statistical analysis of number of grains/cob. Treatment (9) 40 kg/ha sulfur + 25 kg/ha zinc recorded significant and highest number of grains/cob (533.8). However, treatment (6) 30 kg/ha sulfur + 25 kg/ha zinc and treatment (8) 40 kg/ha sulfur + 20 kg/ha zinc were found to be statistically at par with 40 kg/ha sulfur + 25 kg/ha zinc. Wang *et al*. (2014) stated that sulfur application increases the grain yield of maize crop.

Table 2. Effect of sulfur and zinc on yield of *rabi* maize.

Sl. No.	Treatment combinations	No. of cobs/plant (cm)	No. of grains/ cob	Seed index (g)	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
1	Sulfur 20 kg/ha +Zinc 15 kg/ha	1.83	417.3	25.07	4.93	12.96	27.5
2	Sulfur 20 kg/ha +Zinc 20 kg/ha	1.87	428.5	25.43	4.97	13.13	27.5
3	Sulfur 20 kg/ha +Zinc 25 kg/ha	2.00	483.8	26.53	5.58	13.79	28.8
4	Sulfur 30 kg/ha +Zinc 15 kg/ha	1.93	460.8	25.73	5.23	13.30	28.2
5	Sulfur 30 kg/ha +Zinc 20 kg/ha	2.10	489.2	27.17	5.83	13.95	29.5
6	Sulfur 30 kg/ha +Zinc 25 kg/ha	2.17	509.6	27.70	6.10	14.12	30.2
7	Sulfur 40 kg/ha +Zinc 15 kg/ha	1.97	471.0	26.33	5.33	13.59	28.2
8	Sulfur 40 kg/ha +Zinc 20 kg/ha	2.23	517.8	28.00	6.20	14.22	30.4
9	Sulfur 40 kg/ha +Zinc 25 kg/ha	2.33	533.8	28.67	6.42	14.36	30.9
	F test	S	S	NS	S	S	S
	Sem (±)	0.10	8.20	0.81	0.10	0.04	0.37
	CD (p=0.05)	0.30	24.58	-	0.31	0.13	1.12

Ehsanullah *et al.* (2015) noted that increase in number of grains/cob was significantly enhanced by the application of zinc.

Yield and yield attributes

Yield and yield attributes were significantly affected by sulfur at different levels. Maize crop fertilized with 150 kg N/ha along with 45 kg S/ha significantly resulted in seeds/cob (30.65), test weight (20.90), grain yield (4.87). It is the best known for its role in the synthesis of proteins, oils and vitamins in maize (Table 2).

Grain yield (t/ha)

The grain yield showed increasing trend with the application of sulfur and zinc in maize. The highest grain yield was obtained with the treatment 40 kg/ha Sulfur + 25 kg/ha Zinc (6.42 t/ha). Treatment with 40 kg/ha Sulfur + 20 kg/ha (6.20) Zinc were found to be statistically at par with 40 kg/ha Sulfur + 25 kg/ha Zinc. Sulfur is associated with the production of crops for superior nutritional and market quality produce (Chaudhary *et al.* 2014).

Stover yield (t/ha)

The stover yield of maize was also influenced by the application of sulfur and zinc. Significantly superior stover yield (14.36 t/ha) was recorded in treatment (9) with 40 kg/ha Sulfur + 25 kg/ha Zinc. However no. par values are observed. The lowest stover yield (12.96) was observed with treatment (1) with 20 kg/ha Sulfur + Zinc 15 kg/ha.

Choudhary *et al*. (2013) obtained a significant increase in grain yield (4606 kg/ha) and stover yield (7115 kg/ha) with application of 40 kg sulfur per ha compared to control. The improvement in growth and yield components by zinc uptake resulted in increase in stover and grain yield.

Harvest index (%)

The data showed that significantly higher harvest index (30.9) was recorded in treatment (9) with application 40 kg/ha Sulfur + 25 kg/ha Zinc. However, treatment (6) with 30 kg/ha Sulfur + 25 kg/ha Zinc and treatment (8) 40 kg/ha Sulfur + 20 kg/ha Zinc were found to be statistically at par with treatment (9) 40 kg/ha Sulfur + 25 kg/ha Zinc.

CONCLUSION

In view of the obtained results, it is concluded that among the studied treatments combined application of 40 kg/ha Sulfur + 25 kg/ha Zinc in treatment (9) was found to be more desirable that gives higher growth parameters, yield attributes, seed yield, stover yield and harvest index in maize crop.

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