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Economics of Soil Application of Zinc and Foliar Application of Boron in Maize (*Zea mays*)

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ABSTRACT

The experiment was conducted in Crop Research Farm, Department of Agronomy during *Zaid* season of 2022-23 at Naini Agricultural Institute, Sam Higginbottom University of Agricultural Technology and Sciences, Prayagraj (U. P.) to study the economics of soil application of zinc and foliar application of boron in maize. The treatments consisted three levels of zinc (5, 10 and 15 kg/ha) and boron (0.5, 1 and 1.5%) as foliar spray and a control. The experiment was laid out in a randomized block design (RBD) with 10 treatments each replicated thrice. Application of 15 kg zinc with boron 1.5% as foliar spray recorded highest crop growth rate (29.99 g/m^2/day), relative growth rate (0.0303 g/g/day), grain yield (6.33 t/ha), stover yield (14.30 t/ha), harvest index (30.7%) and higher gross returns (Rs.109448.00/ha), net returns (Rs.74174.50/ha) and benefit: cost ratio (2.10).

Key words: Economics, zinc, boron, yield attributes

INTRODUCTION

Maize (*Zea mays*) is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as "Queen of cereals" because it has the highest genetic yield potential among the cereals. Maize ranks fifth in total area and sixth in production and productivity (Anonymous, 2016). Maize is one of the important cereal crops next to wheat and rice in the world. As food, it can be consumed directly as green cob, roasted cob and popped grain. Its grain can be used for human consumption in various ways such as corn meal, fried grain and flour. Its grain has high nutritive value containing 66.2% starch, 11.1% protein, 7.12% oil and 1.5% minerals. Moreover, it contains 90 mg carotene, 1.8 mg niacin, 0.8 mg thiamin and 0.1 mg riboflavin per 100 g grains (Pratap *et al.,* 2016). Improved maize shoot biomass with increasing Zn supply indicated that adequate Zn led to assimilation of the available supply (Liu *et al.,* 2017). Zn is a micronutrient which enhances the grain productivity in the maize production. From this, it might be noted that nutrients do not work in isolation and therefore balanced nutrition is required to enhance the productivity and quality of hybrid maize (Rakesh, 2016). Fakir *et al.* (2016) registered significantly higher number of spikelets/ spike, number of grains/spike, 1000-seed weight and grain yield after boron application. Hence, an experiment was conducted to study the economics of soil application of zinc and foliar application of boron in maize.

MATERIALS AND METHODS

A field experiment was conducted during *Zaid* season of 2022 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, Sam Higginbottom University of Agricultural Technology and Sciences, Prayagraj, U. P., which is located at 25.28°N latitude, 81.54°E longitude and 98 m altitude above the mean sea level. The experiment was laid out in randomized block design which consisted 10 treatments with T_1: Zinc 5 kg/ ha + Boron 0.5%, T_2: Zinc 5 kg/ha + Boron 1%, T_3: Zinc 5 kg/ha + Boron 1.5%, T_4: Zinc 10 kg/ ha + Boron 0.5%, T_5: Zinc 10 kg/ha + Boron 1%, T_6: Zinc 10 kg/ha + Boron 1.5%, T_7: Zinc 15 kg/ha + Boron 0.5%, T_8: Zinc 15 kg/ha + Boron 1%, T_9: Zinc 15 kg/ha + Boron 1.5% and T_{10}: Control. The experimental site was uniform in topography and sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.38%), medium available N (225 kg/ha), higher available P (19.50 kg/ha) and medium available K (213.7

kg/ha). From germination to harvest, several plant growth characteristics were recorded at regular intervals. Cost of cultivation and gross returns were calculated on the basis of prevailing market prices of different inputs and produce, respectively.

RESULTS AND DISCUSSION

The crop growth rate (g/m^2/day) was recorded during 20-40 DAS, 40-60 DAS, 60-80 DAS and 80 DAS-At harvest and presented in Table 1. During 20-40 DAS, there was no significant difference among the treatments. However, highest crop growth rate (8.25 g/m^2/day) was recorded with the treatments zinc 15 kg/ha + boron 1.5%, whereas minimum crop growth rate (7.29 g/m^2/day) was recorded with control. During 40-60 DAS, there was no significant difference among the treatments. However, highest crop growth rate (18.67 g/m^2/day) was recorded with the treatments zinc 15 kg/ha + boron 1.5%, whereas minimum crop growth rate (17.82 g/m^2/day) was recorded with control. During 60-80 DAS, significantly highest crop growth rate (29.99 g/m^2/day) was recorded with the treatment application of zinc 10 kg/ha + boron 1.5%. However, the treatments zinc 5 kg/ha + boron 1.5% (29.79 g/m^2/day), zinc 10 kg/ha + boron 1% (29.95 g/m^2/day), zinc 15 kg/ha + boron 0.5% (29.86 g/m^2/day), zinc 15 kg/ha + boron 1% (29.94 g/m^2/day) and zinc 15 kg/ha + boron 1.5% (29.88 g/m^2/day) were found to be statistically at par with zinc 10 kg/ha + boron 1.5%. During 80 DAS-At harvest, treatment with zinc 5 kg/ha + boron 1% was recorded with significantly highest crop growth rate (6.76 g/m^2/day) over all the treatments. However, the treatments zinc 5 kg/ha + boron 0.5% (6.58 g/m^2/day) and zinc 10 kg/ha + boron 0.5% (6.51 g/m^2/day) were found to be statistically at par with zinc 5 kg/ha + boron 1%. This progressive increase in crop growth rate was due to increase in sunshine hours which led to increase the rate of photosynthesis resulting in more CGR. These results are in agreement with the findings of Naik *et al.* (2020).

The relative growth rate (g/g/day) was recorded during 20-40 DAS, 40-60 DAS, 60-80 DAS and 80 DAS-At harvest (Table 2). During 20-40 DAS, there was no significant difference among the treatments. However, highest relative growth rate (0.0303 g/g/day) was recorded with the treatments zinc 15 kg/ha + boron 0.5%, whereas minimum relative growth rate (0.0286 g/g/day) was recorded with zinc 15 kg/ha + boron 1%. During 40-60 DAS, there was no significant difference among the treatments. However, highest relative growth rate (0.0370 g/g/day) was recorded with the treatments control, whereas minimum relative growth rate (0.0346 g/g/day) was recorded with zinc 10 kg/ha + boron 1.5%, zinc 15 kg/ha + boron 1% and zinc 15 kg/ha + boron 1.5%. During 60-80 DAS, there was no significant difference among the treatments. However, highest relative growth rate (0.0310 g/g/day) was recorded with the treatments zinc 5 kg/ha + boron 0.5%, whereas minimum relative growth rate (0.0290 g/g/day) was recorded with zinc 15 kg/ha + boron 1.5%.

Table 1. Effect of soil application of zinc and foliar application of boron on crop growth rate (g/m^2/day) of maize

Treatment	Crop growth rate (g/m^2/day)			
	20-40 DAS	40-60 DAS	60-80 DAS	80-DAS At Harvest
1. Zinc 5 kg/ha+Boron 0.5%	7.33	17.85	29.26	6.58
2. Zinc 5 kg/ha+Boron 1%	7.58	17.94	29.19	6.76
3. Zinc 5 kg/ha+Boron 1.5%	7.75	18.11	29.79	6.14
4. Zinc 10 kg/ha+Boron 0.5%	7.59	18.15	29.41	6.51
5. Zinc 10 kg/ha+Boron 1%	7.92	18.31	29.95	6.16
6. Zinc 10 kg/ha+Boron 1.5%	8.00	18.43	29.99	6.35
7. Zinc 15 kg/ha+Boron 0.5%	8.05	18.03	29.86	6.21
8. Zinc 15 kg/ha+Boron 1%	8.04	18.54	29.94	6.12
9. Zinc 15 kg/ha+Boron 1.5%	8.25	18.67	29.88	6.26
10. Control	7.29	17.82	29.04	6.17
F-test	NS	NS	S	S
S. Em±	0.35	0.20	0.16	0.12
C. D. (P=0.05)	-	-	0.49	0.35

S–Significant and NS–Not Significant.

Table 2. Effect of soil application of zinc and foliar application of boron on relative growth rate (g/g/day) of maize

Treatment	Relative growth rate (g/g/day)			
	20-40 DAS	40-60 DAS	60-80 DAS	80-DAS At Harvest
1. Zinc 5 kg/ha+Boron 0.5%	0.0290	0.0366	0.0310	0.0043
2. Zinc 5 kg/ha+Boron 1%	0.0296	0.0353	0.0303	0.0050
3. Zinc 5 kg/ha+Boron 1.5%	0.0293	0.0356	0.0303	0.0043
4. Zinc 10 kg/ha+Boron 0.5%	0.0296	0.0363	0.0306	0.0043
5. Zinc 10 kg/ha+Boron 1%	0.0293	0.0350	0.0306	0.0040
6. Zinc 10 kg/ha+Boron 1.5%	0.0290	0.0346	0.0300	0.0040
7. Zinc 15 kg/ha+Boron 0.5%	0.0303	0.0350	0.0306	0.0043
8. Zinc 15 kg/ha+Boron 1%	0.0286	0.0346	0.0300	0.0043
9. Zinc 15 kg/ha+Boron 1.5%	0.0290	0.0346	0.0290	0.0040
10. Control	0.0293	0.0370	0.0306	0.0046
F test	NS	NS	NS	NS
S. Em±	0.00	0.00	0.00	0.00
C. D. (P=0.05)	-	-	-	-

NS–Not Significant.

During 80 DAS-At harvest, there was no significant difference among the treatments. However, highest relative growth rate (0.0050 g/g/day) was recorded with the treatments zinc 5 kg/ha + boron 1%, whereas minimum relative growth rate (0.0070 g/g/day) was recorded with zinc 10 kg/ha + boron 1%, zinc 10 kg/ha + boron 1.5% and zinc 15 kg/ha + boron 1.5%.

Significantly maximum grain yield (6.33 t/ha) was recorded in T_9 with application of zinc 15 kg/ha + boron 1.5% superior over all the treatments (Table 3). However, T_6 zinc 10 kg/ha + boron 1.5% (6.18 t/ha) and T_8 zinc 15 kg/ha + boron 1% (6.26 t/ha) were found to be statistically at par with T_9, zinc 15 kg/ha + boron 1.5%. Production of photosynthates and their translocation to sink depends upon availability of mineral nutrients whose availability has increased the zinc uptake also. Most of the photosynthetic pathways are dependent on enzymes and co-enzymes, which are synthesized by mineral nutrients such as nitrogen, phosphorus, and potassium activated by zinc. The increase in yield attributes due to the application of zinc was caused by higher chlorophyll contents, which had apparently a positive effect on photosynthetic activity, synthesis of metabolites and growth-regulating substances, oxidation and metabolic activities and ultimately better growth and development of crop, which led to increase in yield of maize. These results are in agreement with the findings of Anjum *et al.* (2017). Boron plays a vital role in increasing seed yield because zinc and boron take place in many physiological processes of plant such as chlorophyll formation, stomata regulation, starch utilization, which enhance seed yield. Boron is required for many physiological processes and plant growth. Adequate nutrition is critical for increasing yields and quality of crops. These results are in confirmatory with the work of Alimuddin *et al.* (2020).

Table 3. Effect of soil application of zinc and foliar application of boron on yield attributes and yield of maize

Treatment	Grain yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
1. Zinc 5 kg/ha+Boron 0.5%	5.31	12.96	29.1
2. Zinc 5 kg/ha+Boron 1%	5.47	13.13	29.4
3. Zinc 5 kg/ha+Boron 1.5%	5.85	13.59	30.1
4. Zinc 10 kg/ha+Boron 0.5%	5.58	13.30	29.6
5. Zinc 10 kg/ha+Boron 1%	6.05	13.95	30.3
6. Zinc 10 kg/ha+Boron 1.5%	6.18	14.12	30.4
7. Zinc 15 kg/ha+Boron 0.5%	5.93	13.79	30.1
8. Zinc 15 kg/ha+Boron 1%	6.26	14.22	30.5
9. Zinc 15 kg/ha+Boron 1.5%	6.33	14.30	30.7
10. Control	5.21	12.48	29.5
F test	S	S	S
S. Em±	0.12	0.07	0.24
C. D. (P=0.05)	0.38	0.20	0.49

S–Significant.

Significantly maximum stover yield (14.30 t/ha) was recorded in T_9, with application of zinc 15 kg/ha + boron 1.5% superior over all the treatments. However, T_6 zinc 10 kg/ha + boron 1.5% (14.12 t/ha) and T_8 zinc 15 kg/ha + boron 1% (14.22 t/ha) which were found to be statistically at par with T_9 zinc 15 kg/ha + boron 1.5%. Zinc fertilization had beneficial effect on physiological process, plant metabolism and plant growth, which led to higher yield. Increase in green cob and green fodder yield with application of zinc and the

Table 4. Effect of soil application of zinc and foliar application of boron on economics of maize

Treatment	Cost of cultivation	Gross returns	Net returns	B:C Ratio
1. Zinc 5 kg/ha+Boron 0.5%	32988.50	77731.33	44742.83	1.36
2. Zinc 5 kg/ha+Boron 1%	33368.50	80503.33	47134.83	1.41
3. Zinc 5 kg/ha+Boron 1.5%	33798.50	88282.33	54483.83	1.61
4. Zinc 10 kg/ha+Boron 0.5%	33773.50	86195.66	52422.16	1.55
5. Zinc 10 kg/ha+Boron 1%	34153.50	96245.33	62091.83	1.82
6. Zinc 10 kg/ha+Boron 1.5%	34583.50	101517.00	66933.50	1.94
7. Zinc 15 kg/ha+Boron 0.5%	34463.50	92930.33	58466.83	1.70
8. Zinc 15 kg/ha+Boron 1%	34843.50	106741.33	71897.83	2.06
9. Zinc 15 kg/ha+Boron 1.5%	35273.50	109448.00	74174.50	2.10
10. Control	31483.50	70756.00	39272.50	1.25

results are supported by the findings of Das *et al.* (2020).

Significantly maximum harvest index (30.7%) was recorded in T_9 with the application of zinc 15 kg/ha + boron 1.5% superior over all the treatments (Table 3). However, T_5 zinc 10 kg/ha + boron 1% (30.3 %), T_6 zinc 10 kg/ha + boron 1.5% (30.4%), and T_8 zinc 15 kg/ha + boron 1% (30.5%) were found to be statistically at par with T_9 zinc 15 kg/ha + boron 1.5%. This finding is in close agreement with those of Shrestha (2016). Further, favourable influence of zinc application on physiological and metabolic processes of the plants ultimately enhanced stover yield leading to higher harvest index.

Gross returns, net returns and benefit: cost ratio were significantly influenced due to different treatments (Table 4). Higher gross returns were recorded with the zinc 15 kg/ha + boron 1.5% (Rs.109448.00/ha) over rest of the treatments followed by zinc 15 kg/ha + boron 1% (Rs.106741.33/ha), whereas minimum gross returns were recorded with control (Rs.70756.00/ha). Higher net returns were recorded with the treatment zinc 15 kg/ha + boron 1.5% (Rs.74174.50/ha) over rest of the treatments followed by zinc 15 kg/ha + boron 1% (Rs.71897.83/ha), whereas minimum net returns were recorded in control (Rs.39272.50/ha). Higher benefit: cost ratio was recorded with the treatment zinc 15 kg/ha + boron 1.5% (2.10) over rest of the treatments followed by zinc 15 kg/ha + boron 1% (2.06), whereas lower benefit: cost ratio was recorded in control (1.25).

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