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Research Paper

Effect of zinc and boron on growth, productivity and quality of maize (*Zea mays*)

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ABSTRACT

A two-year field study (*kharif* 2018 and 2019) was conducted at the agronomy research farm of IFTM University, Moradabad, Uttar Pradesh to access the effect of zinc and boron as soil application (SA) and foliar application (FA) on growth, yield and grain quality of maize (*Zea mays* L.). Ten treatments, T_1, no fertilizer; T_2, zinc @ 5 kg/ha (SA); T_3, zinc @ 1 kg/ha (FA); T_4, zinc @ 1 + 1 kg/ha (2 FA); T_5, zinc @ 5 kg/ha (SA) + zinc @ 1 kg/ha (FA); T_6, boron @ 0.5 kg/ha (SA); T_7, boron @ 0.1 kg/ha (FA); T_8, boron @ 0.2 kg/ha (2 FA); T_9, boron @ 0.5 kg/ha (SA) and boron @ 0.1 kg/ha (FA); and T_{10}, zinc @ 5 kg/ha + boron @ 0.5 kg/ha (SA) were composed in randomized block design (RBD) with 3 replications. The findings showed that adding varying amount of Zinc and Boron and applying them in different ways to zinc and boron greatly enhanced the growth, yield and grain quality of maize. With the application of Zn @ 5 kg/ha (SA) + zinc @ 1 kg/ha (FA), the maximum grain yield (5.39 and 5.84 t/ha) was recorded in 2018 and 2019. Similarly, maximum zinc content (25.90 and 25.95 mg/kg) and zinc uptake (121.47 and 133.69 g/ha, respectively) were reported with same treatment. Furthermore, the highest B content (24.95 and 25.08 mg/kg) and B uptake (245.17 and 270.53 g ha^{-1}) were noted with the application of B @ 0.5 kg/ha (SA) and B @ 0.1 kg/ha (FA), respectively. The highest protein content (10.21 and 10.27%) in grain and protein yield (0.55 and 0.60 t/ha) were recorded with T_{10}, Zn @ 5 kg/ha (SA) + B 0.5 kg/ha (SA), respectively.

Key words: Boron, Foliar Application, Maize, Quality, Soil Application, Zinc

Maize is India's third most significant cereal crop, after rice and wheat and also it is known as the "Queen of Cereals" with the largest genetic output potential. Maize is used for human food, livestock feed and as raw material for industries. Zinc deficiency in soils affects the productivity and quality of maize, because of maize is a zinc-responsive crop. Maize is grown on an area of 181.03 million hectares worldwide, yielding 5.73 t/ha and a total annual production of 1,037.93 million metric tonnes. Maize is India's third most important cereal crop, accounting for about 9% of the country's total food security (Jat *et al.,* 2013). Maize is a stable food and a high-quality feed, as well as a key component in thousands of industrial products. It is usually grown across 9.23 million ha, yielding 24.2 million tonnes with an annual production of 2,560 kg/ha. (ICAR-IIMR, 2015). As a result, single homogeneous nutrient recommendations may be ineffective in increasing maize production.

Zinc is an essential mineral that contributes to basic plant metabolic processes and improves maize growth, yield, and quality by promoting chlorophyll formation, photosynthetic activity, nutrient uptake, and protein biosynthesis. The zinc application to field crops either by soil application (SA) or by foliar application (FA) have shown significant impact on growth, yield, nutrient uptake and quality (Singh *et al.,* 2024).

Boron is a compulsory, indispensable element for plant growth and reproduction. It is essential for translocation and carbohydrate metabolism and it also helps with cell formation in plants, plasma membrane integrity, and seed development by encouraging pollination. It's an essential micronutrient that helps flowers produce more nectar, which attracts insects for pollination. Additionally, boron has an essential role in plant cell matabolism and has a significant impact on cell structure. Pollen growth, plasma membrane integrity, and seed development are all supported by pollination (Pereira *et al.,* 2021). Boron deficiency caused sterility in maize, insufficient levels of available boron in soil reduce crop yield, impair grain quality (Guguloth *et al.,* 2022).

The importance of micronutrients in boosting food and agriculture productivity in India is now widely acknowledged. Widespread micronutrient deficits in crops, which are now being observed across the country, have resulted in significant production and nutritional quality losses.

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According to estimates (Zn), over half of the soils used to grow food crops are zinc deficient. In addition to Zn deficiency, boron (B) (33%) and iron (Fe) (15%) deficiencies are reducing crop yield. Although crop response to micronutrient treatment varies depending on types of soil, crops and genotype, agro-climatic conditions, and severity of deficiency, micronutrient fertilization has been shown to have a huge impact on a wide range of crops, including horticultural crops, across the country. According to estimates, proper Zinc (Zn) management contributes approximately 18.4 million tonnes (worth Rs. 2,11,619 million) to key food grain crops. The contribution of B is estimated at about 4.02 million tonnes, assuming 10% of the cultivated area is receiving B fertilization. Micronutrient deficiencies and malnutrition in animals and humans are becoming more prevalent around the world, particularly in India. Crops cultivated in soils deficient in micronutrients have a low level of micronutrients to meet the needs of animals and humans. Micronutrient research provides vital information for ensuring food security and the well-being of animals and humans while minimising environmental impact (Shukla *et al.,* 2012).

With the progression of time and advancement in all areas, increased awareness of the health and nutrition sectors is required at both the national and international levels. Emphasis should be given to the social, economic, and health consequences of micro-nutrient deficiencies and provide significant funding opportunities for the development of sustainable, agriculture-based approaches to prevent micro-nutrient deficiencies (Cakmak *et al.,* 2011). Hence, the current study was conducted to find-out the suitable doses and method of application of Zinc and Boron for quality maize production.

MATERIALS AND METHODS

A field experiment entitled "Effect of Zinc and Boron on grain quality of maize (*Zea mays* L.)" was conducted at Agronomy Research Farm, IFTM University, Moradabad (U.P.), India during the *kharif* season 2018 and 2019. The aim of the experiment was to investigate the effect of Zinc and Boron on grain quality of maize. The experiments having ten treatments *viz.,* T_1, control; T_2, Zinc @ 5 kg/ha (SA); T_3, Zinc @ 1 kg/ha (FA); T_4, Zinc @ 1 + 1 kg/ha (2 FA); T_5, Zinc @ 5 kg/ha (SA) + Zinc @ 1 kg/ha (FA); T_6, Boron @ 0.5 kg/ha (SA); T_7, Boron @ 0.1 kg/ha (FA); T_8, Boron @ 0.2 kg/ha (2 FA); T_9, Boron @ 0.5 kg/ha (SA) and Boron @ 0.1 kg/ha (FA) and T_{10}, Zinc @ 5 kg/ha + Boron @ 0.5 kg/ha (SA). This study was planned according to randomized block design (RBD) consisting of 3 replications, each replication having 10 plots. Zinc and Boron were applied as per the treatments as soil application (SA) and foliar application (FA). The experimental soil was alluvial, sandy clay loam with moderate water holding capacity. The soil has 7.9 pH and low in organic carbon (0.46%), EC 0.7 mS/cm and low in available nitrogen (123.50 kg/ha), medium in available phosphorus (23.5kg/ha) and potassium (235 kg/ha), and available Zn (0.58 ppm) and B (0.55 ppm). The soil samples were collected randomly to analyze the physico-chemical properties from the experimental site at a depth of 0–15 cm before conducting the experiment.

The maize crop was sown with a seed rate of 20 kg/ha during the *kharif* season. The recommended dose of NPK was applied at the rate of 150, 60 and 40 kg/ha respectively. Urea, DAP, MoP, Zinc sulphate and Borax were used as sources of N, P, K, Zn and B, respectively. Full dose of DAP, MoP and doses of soil application Zn and B were applied at the time of planting. Half of Urea was applied at the time of planting and the remaining quantity of the nitrogen was top dressed in two equal splits. Zn and B foliar application were applied as per the treatments at 30 days after sowing (DAS) and 40 days after sowing (DAS) diluting in 400 liter of water. All other agronomic practices were kept uniform for all the plots of the experiment.

Observations on desired parameters were recorded using standard procedures. Dry matter of randomly selected plants was recorded and calculated using electronic balance at different growth stages. Produce was separated and threshed by hand, cleaned and sun dried to bring the moisture content to 13 per cent and the weight of grain was recorded. Five plants in each plot were marked at random and tagged permanently for recording biometric observations.

Absolute growth rate (AGR)

Absolute growth rate (AGR) is the dry matter production per unit time (g/day), which was calculated by using the formula as given by Radford (1967).

$$\mathrm{AGR} = W_2 – W_1 / t_2 – t_1$$

Where,

W_1 = Dry weight of the plant (g) at time t_1

W_2 = Dry weight of the plant (g) at time t_2

t_1 = time of first observation

t_2 = time of second observation

Crop growth rate (CGR)

It indicates overall growth rate of a crop plant. It is measured after a fixed period of time irrespective of the previous growth rate, which was calculated by using the formula given by Watson (1956).

$$\mathrm{CGR} = W_2 – W_1 / t_2 – t_1$$

Where,

W_1 and W_2 are plant dry weights at time t_1 and t_2, respectively. It was expressed in terms of g/m²/day.

RESULTS AND DISCUSSION

Growth attributes

Dry matter accumulation (g/plant)

It is evident form the result that dry matter accumulation by maize plant was favorably affected by treatment receiving Zn and B as compared to unfertilized plot at all the growth stages (Table 1). The higher values of this parameters were observed when combine application of Zn - 5 kg/ha SA + B 0.5 kg/ha SA was applied. This might be due to the better availability of nutrients to the growing roots and due to the maximum plant height and more number of leaves recorded in this treatment because of photosynthesis enhanced in the presence of Zn and B, which indicates that the micronutrient helps to activate the synthesis of tryptophan and precursor of IAA, which is responsible to stimulation the plant growth and accumulation of biomass. The acceleration in photosynthesis is evident for the better vegetative growth. These results are in conformity with those already reported by Singh *et al.,* (2017).

Absolute growth rate (g/day) and crop growth rate (g/m^2/day)

The AGR and CGR were lowest in control plot during both the year of study and it increased with increasing rate of Zn and B application (Table 1). Maximum absolute growth rate (AGR) of maize was recorded with the application of Zn - 5 kg/ha SA + B 0.5 kg/ha SA at all stages. This might be due to progressive increase in crop growth such as maximum number of leaves and dry matter accumulation per plant and resulted activation of different physiological processes *viz.* stomatal regulation, chlorophyll formation, enzyme activation and biochemical processes due to foliar application of Zn and B, which resulted in increased dry matter production. Similarly, crop growth rate (CGR) of maize was also recorded significantly maximum with the application of Zn - 5 kg/ha SA + B 0.5 kg/ha SA at all growth stages. This progressive increase in crop growth was due to increase in chlorophyll content, maximum number of leaves and dry matter accumulation and resulted activation of different physiological processes *viz.* stomatal

Table 1. Effect of Zn and B application on dry matter accumulation, absolute growth rate and crop growth rate of maize

Treatment	2018							2019						
	DMA (g/plant)	AGR (g/day)			CGR (g/m^2/day)			DMA (g/plant)	AGR (g/day)			CGR (g/m^2/day)		
		30 - 60 DAS	60 - 90 DAS	90 - 120 DAS	30 - 60 DAS	60 - 90 DAS	90 - 120 DAS		30 - 60 DAS	60 - 90 DAS	90 - 120 DAS	30 - 60 DAS	60 - 90 DAS	90 - 120 DAS
T_1, Control	112.50	1.390	1.675	0.475	19.45	23.45	6.65	115.62	1.457	1.746	0.437	20.40	24.44	6.11
T_2, Zinc @ 5 kg/ha (SA)	130.33	1.843	1.878	0.333	25.82	26.29	4.67	133.52	1.958	1.917	0.272	27.41	26.84	3.80
T_3, Zinc @ 1 kg/ha (FA)	119.67	1.713	1.722	0.311	23.96	24.11	4.36	135.15	1.751	1.843	0.658	24.51	25.80	5.21
T_4, Zinc @ 1 + 1 kg/ha (Two FA)	144.67	2.057	1.889	0.522	28.78	26.44	7.31	149.60	2.109	2.021	0.482	29.53	28.29	6.74
T_5, Zinc @ 5 kg/ha (SA) + Zinc @ 1 kg/ha (FA)	150.67	2.270	1.767	0.622	31.73	24.73	8.71	155.41	2.354	1.813	0.630	32.96	25.39	8.82
T_6, Boron @ 0.5 kg/ha (SA)	142.00	1.880	2.067	0.489	26.29	28.93	6.84	146.52	1.902	2.237	0.433	26.62	31.32	6.07
T_7, Boron @ 0.1 kg/ha (FA)	125.42	1.823	1.767	0.336	25.51	24.73	4.71	130.25	1.880	1.833	0.358	26.32	25.67	5.01
T_8, Boron @ 0.2 kg/ha (Two FA)	146.67	2.267	1.700	0.567	31.73	23.80	7.93	152.05	2.333	1.776	0.584	32.66	24.86	8.18
T_9, Boron @ 0.5 kg/ha (SA) and Boron @ 0.1 kg/ha (FA)	151.67	2.390	1.700	0.578	33.44	23.80	8.09	155.67	2.397	1.846	0.538	33.55	25.84	7.54
T_{10}, Zinc @ 5 kg/ha + Boron @ 0.5 kg/ha (SA)	155.00	2.820	1.489	0.456	39.51	20.84	6.38	160.15	2.904	1.567	0.454	40.66	21.93	6.36
SEm±	1.71	0.030	0.021	0.005	0.29	0.24	0.07	1.92	0.042	0.019	0.005	0.30	0.34	0.10
CD (P=0.05)	5.13	0.090	0.063	0.014	0.87	0.73	0.22	5.75	0.126	0.056	0.014	0.89	1.01	0.29

SA= Soil application, FA= Foliar Application, DMA, Dry matter accumulation; AGR, Absolute growth rate; CGR, Crop Growth rate regulation, chlorophyll formation, enzyme activation and biochemical processes due to foliar application of micronutrients which resulted in increased dry matter production. So the CGR were significantly increased. These results are conformity with those already reported by Khan *et al.,* (2010).

Yield attributes and yields

100-grains weight (g)

As regards the influence of Zn and B significantly influenced the 100-grains weight (Table 2). The result clearly indicates that the application of Zn - 5 kg/ha (SA) + B - 0.5 kg/ha (SA) produced maximum seed index as compared to other treatments. The increase in yield attributing characters with the application of Zn - 5 kg/ha SA + B - 0.5 kg/ha (SA) may be due to the availability of nutrients even during later reproductive and grain filling stage, which resulted in increased rate of photosynthesis, which has direct bearing on yield components and yield.

The maximum seed index is attributed to complementary role of boron in the reproduction. Usually, Zn and B are required in minute amounts but impart significant effects on metabolism by working synergistically with hormones and enzymes. Because of the Zn and B have directly influenced the physiological and biochemical parameters of maize which directly improves the productivity of the crop by improving various yield attributing characters, results are in conformity with those already reported by Tahir *at al.,* (2009); Deswal and Pandurangam (2018) and Singh *et al.,* (2017).

Grain and stover yields (t/ha)

The application of Zn - 5 kg/ha (SA) + B - 0.5 kg ha (SA) increased the stover and grain yield of maize as compared with other treatments (Table 2). The increase in stover and grain yield of maize might be due to the increased availability of essential nutrients to the crop resulting from the cumulative effect of organic sources of nutrient applied to wheat crop. The Zn and B have directly involved in activation of several plant enzymes that are involved in carbohydrate metabolism, protein synthesis and pollen formation ultimately increase in number of grains/cob and cob length has positively affected the grain yield and influenced the physiological and biochemical parameters of maize which directly improves the productivity of the crop by improving various yield attributing characters (Deswal and Pandurangam, 2018; Shivay and Prasad, 2014 and Rana *et al.,* 2017).

Quality parameters

Zinc content and uptake

The different treatment of Zn and B application had significant effect on Zn content in maize (Table 3). Results showed that all the Zn and B treatments significantly influenced the Zn content over control during the experiments. The Zn content (25.90 and 25.95 g/kg) was recorded with the application of Zinc @ 5 kg/ha (SA) + Zinc 1 kg/ha (FA) over the rest treatments in present investigation. It might be attributed due to high Zn application. Results are in conformity with those already reported by Tariq *et al.,* (2014) and Mohsin *et al.,* (2017).

Table 2. Effect of Zn and B application on yield of maize

Treatment	2018				2019			
	Grains/ cob	100 seed weight (g)	Stover yield (t/ha)	Grain yield (t/ha)	Grains/ cob	100-seed weight t (g)	Stover yield (t/ha)	Grain yield (t/ha)
T_1, Control	327.33	25.10	4.25	2.81	332.50	25.15	4.35	3.03
T_2, Zinc @ 5 kg/ha (SA)	398.30	26.40	4.85	3.50	405.50	27.11	4.95	3.65
T_3, Zinc @ 1 kg/ha (FA)	369.19	26.23	4.41	3.07	374.53	26.40	4.51	3.35
T_4, Zinc @ 1 + 1 kg/ha (Two FA)	425.96	26.57	5.73	4.14	433.50	26.59	6.03	4.55
T_5, Zinc @ 5 kg/ha (SA) + Zinc @ 1 kg/ha (FA)	458.62	26.73	6.27	4.69	465.50	27.30	6.55	5.15
T_6, Boron @ 0.5 kg/ha (SA)	412.39	26.47	4.87	3.50	416.53	26.52	4.92	3.83
T_7, Boron @ 0.1 kg/ha (FA)	377.64	26.30	4.66	3.30	381.10	26.44	4.78	3.65
T_8, Boron @ 0.2 kg/ha (Two FA)	432.61	26.60	5.96	4.37	436.20	27.11	6.24	4.63
T_9, Boron @ 0.5 kg/ha (SA) and Boron @ 0.1 kg/ha (FA)	503.67	26.87	6.30	4.84	511.53	27.90	6.66	5.35
T_{10}, Zinc @ 5 kg/ha + Boron @ 0.5 kg/ha (SA)	514.52	27.40	6.33	5.39	520.43	28.60	6.75	5.84
SEm±	4.26	0.33	0.456	0.41	5.17	0.28	0.258	0.283
CD (P=0.05)	12.75	0.99	0.152	1.21	15.48	0.84	0.086	0.094

SA= Soil application, FA= Foliar Application

From the results of this study, it was evident that Zn and B application greatly affected the Zn uptake by maize (Table 3). Results showed that all the Zn and B treatments significantly increased the Zn uptake over control during the experiments. The Zn uptake (121.47 and 133.69 g ha^{-1}) was recorded with the application of Zinc @ 5 kg/ha (SA) + Zinc 1 kg/ha (FA) followed by Zinc @ 1 + 1 kg/ha (2 FA) and Zinc @ 5 kg/ha + Boron 0.5 kg/ha (SA). Minimum Zn uptake was recorded in control plot in both the years. It might be attributed due to high Zn content in maize so Zn uptake was increased. Same findings also reported by Kanwal *et al.,* (2010), Chaudhary *et al.,* (2022) and Satybhan *et al.,* (2024).

Boron content and uptake

It was evident that B application greatly affected the B content (Table 4). Results showed that all the B treatments significantly increased the B content in maize over the rest treatments. The significantly maximum B content (24.95 and 25.08 mg/kg) was recorded with the application of Boron @ 0.5 kg/ha (SA) and Boron 0.1 kg/ha (FA). It might be attributed due to high B application. Results are in conformity with those already reported by Islam and Jahiruddin, (2008), Rehim *et al.,* (2018) and Satybhan *et al.,* (2024).

From the results of this study, it was evident that B application greatly affected the B uptake (Table 4). Results

Table 3. Zn content and Zn uptake by maize as influenced by Zinc and Boron fertilization

Treatment	Zn Content (mg/kg)		Zn Uptake (g/ha)	
	2018	2019	2018	2019
T_1, Control	16.52	16.55	46.35	50.06
T_2, Zinc @ 5 kg/ha (SA)	23.52	23.60	81.59	86.19
T_3, Zinc @ 1 kg/ha (FA)	25.12	25.22	77.09	84.54
T_4, Zinc @ 1 + 1 kg/ha (Two FA)	24.11	24.16	107.70	109.98
T_5, Zinc @ 5 kg/ha (SA) + Zinc @ 1 kg/ha (FA)	25.90	25.95	121.47	133.69
T_6, Boron @ 0.5 kg/ha (SA)	16.55	16.60	57.93	63.50
T_7, Boron @ 0.1 kg/ha (FA)	16.84	16.88	55.57	61.65
T_8, Boron @ 0.2 kg/ha (Two FA)	17.00	17.12	74.27	79.18
T_9, Boron @ 0.5 kg/ha (SA) and Boron @ 0.1 kg/ha (FA)	17.21	17.22	83.21	92.16
T_{10}, Zinc @ 5 kg/ha + Boron @ 0.5 kg/ha (SA)	23.71	23.80	99.85	80.62
SEm±	0.28	0.27	1.13	0.92
CD (P=0.05)	0.83	0.80	3.39	2.77

SA= Soil application, FA= Foliar Application

Table 4. B content and B uptake by maize as influenced by Zinc and Boron fertilization

Treatment	B Content (mg/kg)		B Uptake (g/ha)	
	2018	2019	2018	2019
T_1, Control	13.62	13.71	53.17	57.63
T_2, Zinc @ 5 kg/ha (SA)	17.73	17.83	66.07	69.97
T_3, Zinc @ 1 kg/ha (FA)	18.02	18.12	58.63	64.40
T_4, Zinc @ 1 + 1 kg/ha (Two FA)	19.07	19.19	78.97	87.30
T_5, Zinc @ 5 kg/ha (SA) + Zinc @ 1 kg/ha (FA)	19.41	19.63	91.03	100.50
T_6, Boron @ 0.5 kg/ha (SA)	16.60	16.68	145.30	158.80
T_7, Boron @ 0.1 kg/ha (FA)	22.47	22.50	149.00	166.57
T_8, Boron @ 0.2 kg/ha (Two FA)	23.57	23.69	244.20	266.51
T_9, Boron @ 0.5 kg/ha (SA) and Boron @ 0.1 kg/ha (FA)	24.95	25.08	245.17	270.53
T_{10}, Zinc @ 5 kg/ha + Boron @ 0.5 kg/ha (SA)	23.21	23.23	211.90	224.37
SEm±	0.516	0.439	1.23	1.89
CD (P=0.05)	1.545	1.314	3.69	5.66

SA= Soil application, FA= Foliar Application

Table 5. Protein content and Protein yield by maize as influenced by Zinc and Boron fertilization

Treatments	Protein Content (%)		Protein Yield (t/ha)	
	2018	2019	2018	2019
T_1, Control	8.75	8.81	0.25	0.27
T_2, Zinc @ 5 kg/ha (SA)	9.15	9.21	0.32	0.34
T_3, Zinc @ 1 kg/ha (FA)	9.50	9.56	0.29	0.32
T_4, Zinc @ 1 + 1 kg/ha (Two FA)	9.44	9.55	0.39	0.44
T_5, Zinc @ 5 kg/ha (SA) + Zinc @ 1 kg/ha (FA)	10.10	10.24	0.47	0.53
T_6, Boron @ 0.5 kg/ha (SA)	9.34	9.36	0.33	0.36
T_7, Boron @ 0.1 kg/ha (FA)	9.50	9.50	0.31	0.35
T_8, Boron @ 0.2 kg/ha (Two FA)	9.55	9.56	0.42	0.44
T_9, Boron @ 0.5 kg/ha (SA) and Boron @ 0.1 kg/ha (FA)	9.45	9.50	0.46	0.51
T_{10}, Zinc @ 5 kg/ha + Boron @ 0.5 kg/ha (SA)	10.21	10.27	0.55	0.60
SEm±	0.15	0.11	0.001	0.001
CD (P=0.05)	0.45	0.34	0.002	0.002

SA= Soil application, FA= Foliar Application

showed that all the B treatments significantly increased the B uptake over control during the experiments. The significantly maximum B uptake (245.17 and 270.53 g ha^{-1}) was recorded with the application of Boron @ 0.5 kg/ha (SA) and Boron 0.1 kg/ha (FA). It might be attributed due to high B content in maize so B uptake was increased. Same findings also reported by Panhwar *et al.,* (2011) and Satybhan *et al.,* (2024).

Protein content and Protein yield

Application of Zn and B recorded the augmented protein content in maize (Table 5). Results showed that all the Zn and B treatments significantly increased the protein content over control during the experiments. The significantly maximum protein content (10.21 and 10.27 %) was recorded with the application of Zinc @ 5 kg/ha + Boron 0.5 kg/ha (SA). It might be attributed due to Zn increase the nitrogen uptake and nitrogen content is directly influenced on protein content. Same findings also reported by Shivaty *et al.,* (2001); Ziaeyana and Rajaiea (2009); Mona and Azab (2015), Tahir *et al.,* (2016) and Satybhan *et al.,* (2024).

From the results of this study, it was evident that Zn and B application greatly affected the protein yield of maize (Table 5). Results showed that all the Zn and B treatments significantly increased the protein yield over control during the experiments. The significantly maximum protein yield (0.55 and 0.60 t ha^{-1}) was recorded with the application of Zinc @ 5 kg/ha + Boron 0.5 kg/ha (SA). It might be attributed due to high protein content in maize finally protein yield was increased. Same findings also reported by Asadollah *et al.,* (2010) and Satybhan *et al.,* (2024).

On the basis of two years field study it may be concluded that the T_5, Zinc @ 5 kg/ha (SA) + Zinc @ 1 kg/ha (FA) was more effective for the zinc content and zinc uptake in maize grain and T_9, Boron @ 0.5 kg/ha (SA) and Boron @ 0.1 kg/ha (FA) was found more effective for the boron content and boron uptake in maize grain. However, protein content and yield was found higher under T10, Zinc @ 5 kg/ha+Boron @ 0.5 kg/ha (SA).

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