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ORIGINAL RESEARCH ARTICLE

Evaluation of foliar spray of zinc and boron on growth, flowering and yield of tomato (*Solanum lycopersicum* cv. Srijana) under polytunnel in Nepal

Prabina Bhujel[1*], Pankaj Kumar Yadav[2], Sujan Lamichhane[1] and Nirajan Bhandari[3]

[1]Faculty of Agriculture, Agriculture and Forestry University, Chitwan - 44200, Nepal
[2]Department of Plant Science, College of Agricultural and Life Sciences, University of Idaho - 83341, USA
[3]College of Natural Resource Management, Agriculture and Forestry University, Pakhribas, Dhankuta, Nepal
[*]Corresponding author's E-mail: prabina.bhujel23@gmail.com

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ABSTRACT

This research was conducted in Budhanilkantha, Kathmandu from February to June 2023 to study the effects of different concentrations on growth, flowering and yield of tomato in Randomized Complete Block Design (RCBD) with five treatments: control (T_0), two levels of chelated zinc (30 ppm - T_1 and 60 ppm - T_2), and two levels of borax (30 ppm - T_3 and 60 ppm - T_4), applied 15 and 35 days after transplantation (DAT). The results showed that chelated zinc at 30 ppm significantly enhanced plant height (86 cm), leaf number (52.47), branch number (8.21), fruit clusters (19.32), fruit number (22.73), fruit diameter (5.58 cm), fruit weight (59.71 g), and yield (56.56 t/ha). Borax at 30 ppm promoted early flowering (23.70 days). Higher concentrations of both micronutrients resulted in reduced growth and yield. The findings suggest that foliar application of 30 ppm chelated zinc and borax can optimize growth and yield of tomato. The study highlights the potential of these easily accessible micronutrient sources to significantly enhance tomato productivity under polytunnel cultivation.

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INTRODUCTION

Tomato (*Solanum lycopersicum*), member of Solanaceae family, is an important vegetable grown in Nepal (Bastola *et al*., 2020). Tomato is one of the most popular vegetables with great medicinal value and it contains large amount of sugar, starch and minerals (Kumar *et al*., 2022; Lim *et al*., 2024). It contains higher amounts of total sugar (2.5-4.5%), starch (0.6-1.2%), and minerals like potassium, calcium, sodium, magnesium, phosphorus, boron, manganese, zinc, copper, and iron (Chopra *et al*., 2017; Sweta *et al*., 2018). Tomato is grown throughout the agro-climatic region of Nepal at different period of the year. Among the 15 ecological development belts, Central hills which includes Kathmandu valley produced the highest volume of tomato followed by Eastern hills and Central terai respectively (Ghimire *et al*., 2018). The cultivation of tomato in the mid-hills has huge scope. Polytunnel cultivation under these area is widely famous for year round production of tomato and other vegetables. The area, production and productivity in Budhanilkantha were 103 ha, 1230 Mt and 11.94 Mt/ha, respectively (MoAD, 2023). Nutrients are quickly available by foliar application than soil application (Mehdizadeh *et al*., 2013; Kumar *et al*., 2022). Foliar application has resulted in significant increase in yield (Ahmed *et al*., 2023). The physiological role of boron was found in strengthening the cell wall, sugar transport, RNA Metabolism, and also part of cell membranes. Zinc is a constituent of an enzyme (Carbonic Anhydrase) which is essential for nutrient metabolism and plays a role in biomass production (Suganya *et al*., 2020). Zinc is also needed for chlorophyll production, pollen functioning, and fertilization (Kandil *et al*., 2022). Micronutrients are crucial for achieving the maximum potentiality of production. The deficiency of micronutrients is more prevalent in Nepalese soils (Tripathi *et al*., 2022). Similarly, Boron was found to have the lowest average among all countries including Nepal, limiting the yields of many boron requiring plants. The addition of Zn and B has been shown to enhance the product quality of tomatoes in Turkey (Ahmed *et al*., 2023). Boron deficiency can adversely affect tomato flowering and fruiting, reducing not only yield but the product quality (Mousavi & Motesharezadeh, 2020). In Nepal, the productivity of tomato is around 19 Mt/ha but in the Budhanilkantha the productivity is only around 12 Mt/ha which shows a huge gap in productivity. The reasons for this gap are because of various factors but negligence of micronutrients application is one of them.

Micronutrients have an important role in plant activities and foliar application can improve the vegetable growth, fruit set, and yield of tomato by increasing photosynthesis of green plants (Ahmed *et al*., 2021). Among the micronutrients, Zn and B are important for plant nutrition (Sweta *et al*., 2018). Tomatoes require both major and micro nutrients for proper plant growth (Rahi *et al*., 2021). Zinc plays important role on growth and development as well as carbohydrates, protein metabolism and sexual fertilization of plant while B deficiency reduced yield and qualities in tomato (Oliveira *et al*., 2022). The application of Boron, Zinc, Mo, Co, Fe, Mn resulted in improvement of plant growth characters viz., plant height, number of primary branches, compound leaves, tender and mature fruits per plant (Ahmed *et al*., 2021). Micronutrients like Zn, Iron, Mn, Copper, Boron, and Magnesium have an important role in physiology of tomato crops and are required for physiological activities, and hence supplementing micronutrients is essential (Rahman *et al*., 2020). The farmers of Budhanilkantha municipality have less or no knowledge about the application of micronutrients and their value on production. Realizing the scenario of this municipality, the present experiment has been undertaken to know the overall effect of Zn and B on tomatoes. The study aims to evaluate the impact of zinc and boron on tomato performance in Budhanilkantha, Nepal, identifying the effects of different concentrations on flowering, fruiting, yield and finding the optimal zinc and boron dose.

MATERIALS AND METHODS

Experimental details

The experimental site was Prakriti Organic Farm, Buddhanilkantha located in Kathmandu district shown in Figure 1. It lies in the coordinates of 27.765438° N and longitude of 85.365296° E. It is at an elevation of about 1371 meters from mean sea level. The weather data is shown in Figure 2. The experiment was conducted in Randomized Complete Block Design (RCBD) with five treatments were replicated four times with block formation in the field. The size of each plot was 2×1.2 m^2. Soil samples from five different spots of each replication were taken from the soil depth of upper 15 cm using tube auger to record the initial physicochemical properties of the experimental site. From the lab, medium nitrogen concentration was recorded, while phosphorus and potassium have high concentration. The experiment was conducted under a polytunnel using variety Srijana of Tomato. After the formulations of micronutrients i.e., Zn and B, two foliar applications were done. The first application was done after 15 days of seedlings transplantation and second followed 35 days after transplantation (DAT). The treatments details are shown in Table 1.

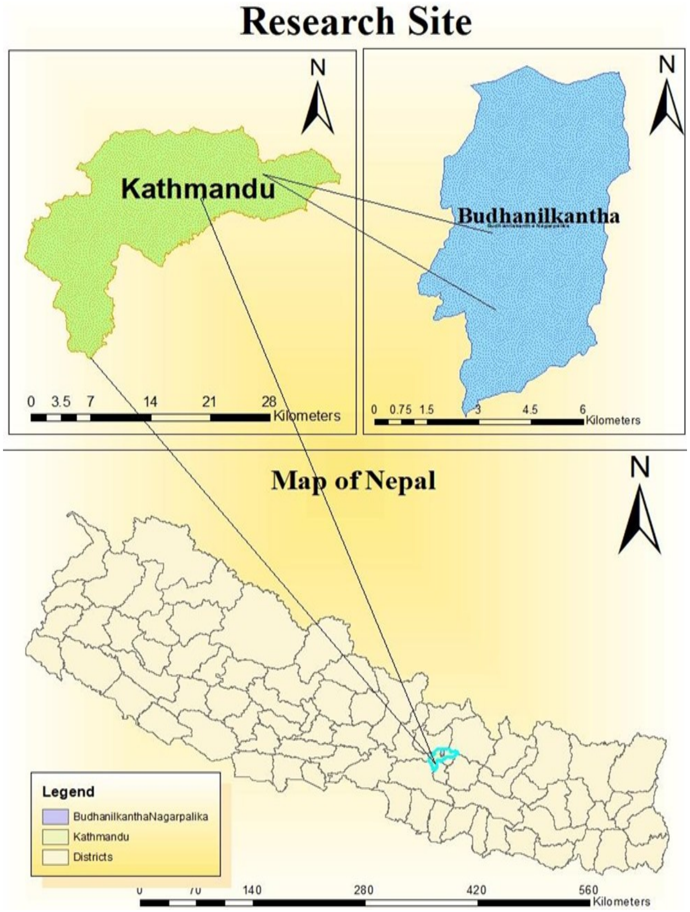

Figure 1. *Map showing experimental site.*

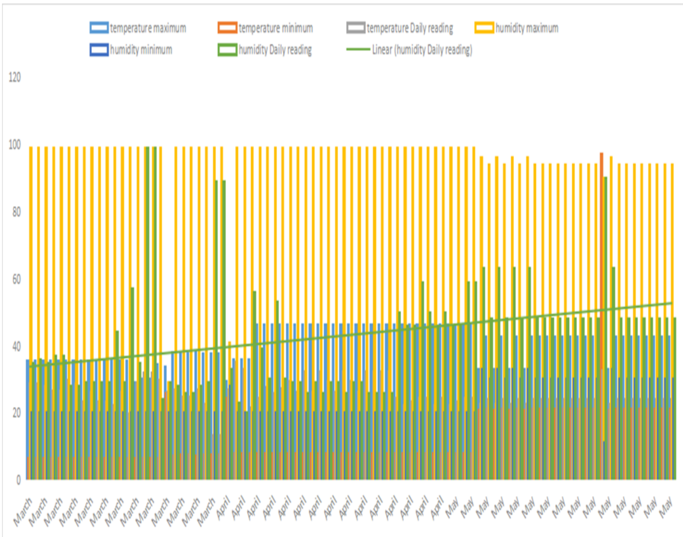

Figure 2. *Weather data of experimental site.*

Table 1. Treatments used during the experiment.

Treatment Details	Dose of micronutrients per spray (mg)	Application Rate	Solutions used per spray (liter)
Control	0	2	2
30 ppm Zn	61.12	2	2
60 ppm Zn	121.33	2	2
30 ppm B	60.65	2	2
60 ppm B	120.89	2	2

RESULTS AND DISCUSSION

The study revealed that the height of the plant was influenced significantly by the application of plant micronutrients at 60 DAT as shown in Table 2. The mean plant height of the tomato was found to be 81.08 cm. The maximum height of the tomato (86.00 cm) was recorded in chelated zinc at the dose of 30 ppm which was followed by Borax 30 ppm (84.77cm) and chelated zinc 60 ppm (81.49 cm). Similarly, minimum plant height was recorded at borax in the concentration of 60 ppm (76.57 cm) and also in the control treatment (76.60 cm). Zinc is believed to have a positive correlation with the height of the plant. But many other factors have been found to affect proper assimilation and usage of applied zinc sources. The factors may be soil type, radiation, moisture etc. (Javadimoghadam *et al*., 2015). Cell division and cell elongation mechanisms were responsible for the increase in length of tomato. Zinc is significant fundamental micronutrient which helps in the development of tryptophan, an antecedent of IAA liable for growth incitement and has an indispensable part in formulation of carbonic anhydrase catalyst which helps in transport of CO_2 in photosynthesis (Nandal & Solaki, 2021). It was also found that in addition with boron, zinc helps in growth of cell walls and cellular proliferation in plants (Vera-Maldonado, *et al*., 2024). Plant leaves number (52.47/plant) at chelated zinc 30 ppm was found higher followed by leaves number (47.67/plant) at borax 30 ppm. Lowest leaves number (40.65/plant) was recorded under control condition followed by borax 60 ppm (44.97/plant) and chelated zinc 60 ppm (46.74/plant). The grand mean of leaves number of tomato plant at 60 DAT was found as 46.78/plant. All the treatment doses of zinc source and boron source have shown the positive influence on the leaves number of tomato plant under the protected system. It may be due to zinc association in the chlorophyll formation which might have favored the cell wall development, cell enlargement and cell division. Gopal & Sarangthem (2018) have found Zn @10kg/ha showed higher number of leaves number (20.07) per plant at 20 DAT. Shain *et al.* (2014) found a higher number of leaves in tomatoes at a combined concentration application of Zn (1250 ppm) and B (1250 ppm). The grand mean for the number of branches among the treatments was 7.72/plant. The result showed that a significantly higher number of branches (8.21/plant) was found in case of chelated zinc 30 ppm. However, it is statistically similar to two treatments which were borax at 30 ppm (8.10/plant) and zinc at 60 ppm (7.83/plant). The lowest number of branches (7.12/plant) was recorded in control condition and this was followed by borax at 60 ppm (7.35/plant).

There was a positive impact of zinc and boron to increase the branch number in tomato. Zinc is responsible for RNA metabolism encouraging formation of carbohydrates, proteins and DNA (Harris & Mathuma, 2015). There was significant variation in responses among the treatments influenced by different levels of micronutrients in cluster numbers of tomato variety Srijana as shown in Table 2. The number of clusters (19.32/plant) was found maximum in chelated zinc 30 ppm which is superior in comparison with others. After that high number of clusters (18.34/plant) was found in borax 30 ppm which was followed by two statistically same results i.e. borax 60 ppm (16.81/plant) and chelated zinc 60 ppm (17.31/plant). Minimum number of clusters (15.21/plant) was obtained in case of control. The mean of the clusters was found to be 17.40/plant. From the above data, we can conclude that use of plant micronutrients is promoted in the cluster number of tomatoes, and it was found that foliar application of zinc at the rate of 30 ppm concentration is much better for the number of tomato flower clusters. Applying zinc at a concentration of 0.4% via foliar application has demonstrated the highest yield of flower bunches per plant, reaching 27.45 (Ullah *et al*., 2015). The most significant number of clusters recorded was 21.6 observed in tomato plants subjected to foliar application of $ZnSO_4$ at a concentration of 12.55 ppm (Ali *et al*., 2015).

Table 2. Plant parameters of tomato cv. Srijana influenced by foliar application of plant micronutrients.

Treatments	Plant height at 60 DAT	Leaves number at 60 DAT	Branches number at 60 DAT	Clusters number at 60 DAT
Control water (no treatment)	76.60^{c}	40.65^{d}	7.12^{b}	15.21^{d}
Chelated zinc (30 ppm)	86.00^{a}	52.47^{a}	8.21^{a}	19.32^{a}
Chelated zinc (60 ppm)	81.49^{b}	46.74^{bc}	7.83^{a}	17.31^{c}
Borax (30 ppm)	84.77^{ab}	47.65^{b}	8.10^{a}	18.34^{b}
Borax (60 ppm)	76.57^{c}	44.97^{c}	7.35^{b}	16.81^{c}
LSD(0.05)	3.43	2.28	0.47	0.59
SE_m(±)	0.49	0.33	0.068	0.08
F- Probability	< 0.001	< 0.001	< 0.01	<0.001
CV, %	2.74	3.18	3.97	2.21
Grand mean	81.08	46.49	7.72	17.40

Note: 0.001,0.01 and 0.05 indicates level of significance at 0.1%, 1% and 5%, respectively, and Treatment means in columns followed by common letters are not significantly different from each other based on DMRT TEST at 5% level of significance.

Table 3. Fruit diameter of tomato cv. Srijana influenced by foliar application of plant micronutrients.

Treatments	Days of Flowering after transplantation	Number of fruits per plant	Fruit diameter (cm)
Control water (no treatment)	27.23[a]	15.27[d]	5.06[b]
Chelated zinc (30 ppm)	24.66[bc]	22.73[a]	5.58[a]
Chelated zinc (60 ppm)	25.83[ab]	17.70[c]	5.40[a]
Borax (30 ppm)	23.70[c]	20.84[b]	5.46[a]
Borax (60 ppm)	25.06[bc]	17.27[c]	5.18[b]
LSD(0.05)	1.49	0.90	0.21
$SE_m(\pm)$	0.217	0.13	0.031
F- Probability	<0.01	<0.001	<0.01
CV, %	3.84	3.13	2.66
Grand mean	25.29	18.76	5.34

Note: 0.001,0.01 and 0.05 indicates level of significance at 0.1%, 1% and 5%, respectively, and Treatment means in columns followed by common letters are not significantly different from each other based on DMRT TEST at 5% level of significance.

Table 4. Fruits weight and yield performance of tomato cv. Srijana influenced by foliar application of plant micronutrients.

Treatments	Fruit weight (g)	Yield (kg/plant)	Yield (kg/plot)	Yield (t/ha)
Control water (no treatment)	53.82[d]	0.82[e]	8.22[e]	34.26[e]
Chelated zinc (30 ppm)	59.71[a]	1.35[a]	13.57[a]	56.56[a]
Chelated zinc(60 ppm)	57.62[b]	1.01[c]	10.19[c]	42.48[c]
Borax (30 ppm)	58.75[a]	1.22[b]	12.24[b]	51.01[b]
Borax (60 ppm)	55.13[c]	0.95[d]	9.52[d]	39.68[d]
LSD(0.05)	1.06	0.051	0.51	2.13
Sem(±)	0.15	0.0074	0.074	0.30
F- Probability	<0.001	<0.001	<0.001	<0.001
CV, %	1.21	3.09	3.09	3.09
Grand mean	57.00	1.07	10.75	44.80

Note: 0.001,0.01 and 0.05 indicates level of significance at 0.1%, 1% and 5%, respectively, and Treatment means in columns followed by common letters are not significantly different from each other based on DMRT TEST at 5% level of significance.

The number of days required for first flowering was significantly influenced by the application of plant micronutrients shown in Table 3. Early flowering (23.70 days) was found in borax at the foliar concentration of 30 ppm. Late flowering (27.23 days) occurred in case of control treatment. All the treatments of plant micronutrients showed positive results for days to early flowering than without the application of micronutrients. The early flowering found in the boron 30 ppm might be associated with the proper influx of required ions in the plants. Boron has been found to enhance photosynthesis and hormonal metabolism (Kohli *et al*., 2023). The presence of diverse ions activates hormonal mechanisms in plants, triggering cell expansion and leading to flower formation. Application of boron and zinc resulted in early flowering at 49.3 days, whereas absence of application led to delayed flowering at 55.5 days (Ali *et al*., 2015). Furthermore, boron significantly influences pollen germination and the growth of pollen tubes (Aasim *et al*., 2022). The grand mean of the fruits number among the treatment was found to be 18.76 per plant. Fruit number (22.73) was found superior at the chelated zinc dose of 30 ppm which was followed by borax at the dose of 30 ppm (20.84/plant), chelated zinc 60 ppm (17.70/plant) and borax at 60 ppm (17.27/plant). The control showed a lower number of fruits (15.27/plant) in tomatoes. Zinc is essential micronutrient that enhances the many enzymatic reactions like manganese and magnesium. It plays a role in RNA metabolism, carbohydrate and protein synthesis, fruit setting and finally increasing the number of fruits in the plant (Harris & Mathuma, 2015). A similar result was obtained in my experiment with chelated zinc at the dose of 30 ppm. Furthermore, this result was also supported by (Gopal & Sarangthem, 2018), in which maximum number of tomato (28.33/plant) fruits by the application of zinc at the dose of 10 kg/ha. Application of NPK along with the 100 ppm of Zn had shown the highest number of fruits per plant (34.43/plant) in the Gujarat Tomato 2 (Singh *et al*., 2017).

The responses of different doses of plant micronutrients showed significant variation as shown in Table 4. Chelated zinc at a concentration of 30 ppm yielded the highest fruit diameter (5.58 cm/fruit) is statistically similar to chelated zinc at 60 ppm (5.40 cm/fruit) and borax at 30 ppm (5.46 cm/fruit). The control treatment resulted in the smallest fruit diameter (5.06 cm/fruit), which is statistically similar to borax at a dose of 60 ppm (5.18 cm/fruit). The mean of the fruit diameter in all the treatments was measured as 5.34 cm/fruit. It was found that there was a positive correlation between the diameter of fruits and application of plant micronutrients. The highest fruit length and diameter (5.1 cm/fruit) were achieved by simultaneously applying zinc and boron through foliar means, without considering the absence of micronutrient application (Ali *et al*., 2015). Similarly, a higher value of tomato diameter was also obtained with a combined application of boron 0.1% and zinc 0.2% with other nutrients (Dixit *et al*., 2018). There was a significant difference between yield per plant and yield per hectare among the treatments treated with varied concentration of plant micronutrients. Yield per plant was highest for the treatment of zinc 30 ppm (1.35kg) followed by borax 30 ppm (1.22 kg), chelated zinc 60 ppm (1.01 kg) and borax 60 ppm (0.95 kg), respectively. The low value of yield per plant was recorded in control. The yield was found to be maximum (56.56 t/ha) in case of chelated zinc 30 ppm and the lowest yield (34.26 t/ha) was observed in control. The grand mean of the yield was 44.80 t/ha. The maximum recorded fruit weight was 59.71 gm per fruit with chelated zinc at a concentration of 30 ppm, and is statistically similar to borax at 30 ppm, which showed a fruit weight of 58.75 gm per fruit. The control condition exhibited the least fruit weight at 53.82 gm per fruit.

The positive impact of foliar application of plant essential micronutrients is shown in Table 4. Zinc 30 ppm showed superior results than any other treatment for maintaining proper weight of tomato. Boron and Zinc contribute to enhanced translocation and increased accumulation of photosynthates from the source to the sink in plants. This is particularly significant as developing fruits function as a crucial metabolic sink. Zinc source however helps in endogenous auxins and productions of other stimulatory compounds, it regulates the permeability of cell walls and allows the mobilizations of water in fruits that contribute to greater fruit length and weight. In accordance with our result, significantly higher fruit weight was also obtained by (Dixit *et al*., 2018) with the combined application of zinc and boron. Zinc and boron increases the fruit weight of tomato (Saha *et al*., 2023). Application of chelated zinc at the concentration of 30 ppm showed superior results. This is due to the maximum expression of all the physiological activities by plants at required concentration of zinc. Zinc becomes necessary for the synthesis of enzyme carbonic anhydrase which supports the transport of CO_2 throughout photosynthesis (Nandal & Solanki, 2021) and thus zinc can improve the effectiveness of photosynthesis and also enhance antioxidant system of tomato plants (Faizan & Hayat, 2019). The application of Zn at 10 mg/kg soil resulted in a 39% and 54% increase in fruit yield for the VCT-1 and Rio Grande tomato variants, respectively, compared to the control variant. Similarly, at 15 mg/kg soil application, the tomato yield improved by 34% and 48% for the two variants, VCT-1 and Rio Grande, respectively (Gurmani *et al*., 2012). Similarly, the highest value of yield (23.40 t/ha) was obtained by the foliar application of 0.4% of zinc (Ullah *et al*., 2015). Kazemi (2013) found that zinc (100 mg/l) with combination to iron had also shown a high value of yield (25.14 t/ha).

Conclusion

This field experiment showed the vital role of micronutrients zinc and boron in enhancing tomato productivity under polytunnel conditions. The foliar application of chelated zinc at 30 ppm proved to be the most effective, significantly improving key growth parameters such as plant height, leaf number, branch development, and fruit yield achieving an optimum yield 56.56 t/ha. Borax at 30 ppm also showed notable improvements, particularly in early flowering and fruit quality. The findings emphasize the importance of precise micronutrient application, revealing a nearly 20 t/ha yield gap between treated and untreated plants, while higher concentrations offered no additional benefits. Therefore, maintaining a concentration of 30 ppm of zinc is optimal for maximizing tomato production and plant health.

DECLARATIONS

Author contribution statement

Conceptualization: P.B. and P.K.Y.; Data curation: PP.B. and P.K.Y.; Investigation: N.B.; Methodology: P.B. and P.K.Y.; Resources: P.B. and P.K.Y.; Software: P.B. and P.K.Y.; Supervision: N.B.; Validation: N.B.; Visualization: P.B. and P.K.Y.; Writing – original draft: P.B. and P.K.Y.; Writing – review & editing: P.B., P.K.Y., N.B, and S.L.; Funding acquisition: P.B. and P.K.Y. All authors have read and agreed to the published version of the manuscript.

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