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EFFECTIVENESS OF MICRONUTRIENT FOLIAR SPRAYS ON TOMATO (*SOLANUM LYCOPERSICUM* L.) GROWTH AND PRODUCTIVITY IN PROTECTED CULTIVATION

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ABSTRACT

The research was carried out at the Horticultural Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, Uttar Pradesh, during the *Rabi* seasons of 2023–24 and 2024–25. The experiment followed a Randomized Block Design (RBD) with three replications and involved 15 treatment combinations of foliar micronutrient applications. The investigation assessed the effect of these treatments on tomato growth and yield traits. Among treatments, T_{14} (Multiplex) consistently outperformed others, achieving a plant height of 181.09 cm, 15.50 branches per plant,fruit length of 4.93 cm, fruit diameter of 5.48 cm, fruit weight of 67.18 g, and total yield in a 250 m^2 area reached 33.28 tonnes.
***Keywords* :** Foliar application,micronutrients, multiplex, *Solanum lycopersicum.*

Introduction

Tomato, scientifically referred to as *Solanum lycopersicum* (L.) or *Lycopersicon esculentum* (Mill.), ranks among the most popular and extensively cultivated vegetable crops globally, often regarded as a "protective food". It plays a critical role not only in maintaining strong bones but also in regulating various bodily functions, such as muscle contractions and the transmission of nerve impulses, which are triggered electrically (Kiferle *et al.,* 2013). The biofortification of crops through the absorption and accumulation of specific micronutrients, along with the careful management of certain compounds, has played a significant role in improving public health, particularly with nutrients like zinc and iron. Both modern biotechnology and traditional breeding methods can aid in the production of these enhanced crops by selecting superior genotypes (Selvakumar and Muthukumar, 2017). Additionally, the advancement and implementation of improved agronomic practices, such as optimizing fertilization through precise nutrient application, can also be beneficial. Two essential micronutrients for plant health are zinc (Zn) and boron (B). Tomatoes, in particular, need both macronutrients and micronutrients to thrive (Kumari and Sarika, 2021). Zn is vital for growth and development, influencing carbohydrate and protein metabolism as well as sexual reproduction in plants (Mehdizadeh *et al.,* 2013). On the other hand, tomatoes that are deficient in B may produce fewer and lower-quality tomatoes. A proper macronutrient-micronutrient balance can improve output (Yassen *et al.,* 2010) and applying micronutrients through foliar methods is both effective and safe (Schwarz *et al.,* 2010). One of the most noticeable signs of iron deficiency in plants is significant leaf chlorosis (Chanda *et al.,* 2011). Boron is known to play a key role in chlorophyll formation. Zinc deficiency in tomatoes can lead to reduced protein synthesis, stunted shoot growth, and ultimately lower yields. Therefore, while the required amounts of micronutrients are small, they are just as essential for plant growth and development as larger quantities of primary and secondary nutrients (Kumari and Sarika, 2021). Conventional fertilizers often fall short in providing precise nutrient delivery, which hampers nutrient use efficiency (NUE) and overall crop yield.

Moreover, the over-application of synthetic fertilizers adversely affects soil health and diminishes microbial diversity (Sathyan, 2022). Tackling these issues has the potential to transform crop nutrition management, enhancing NUE, minimizing environmental effects, and fostering sustainable agricultural practices essential for future global food security (Manikanta *et al.,* 2023). In order to assess the effect of micronutrients on tomato growth and yield an experiment was carried out.

Material and Methods

The present investigation was carried out at the Horticultural Research Farm of the Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, Uttar Pradesh, during the Rabi seasons of 2023-24 and 2024-25 to unveil the effect of varying foliar applications of micronutrients, administered at diverse concentrations, on the growth attributes, yield potential of the NS4266 tomato variety. In the present investigation the design used for analysis of variables was Randomized Block Design (RBD) comprising 3 replications comprising of foliar application of micronutrients total treatment combinations being fifteen. The treatments comprised T_0 (Control); T_1 (Boric acid- 100 ppm); T_2 (Zinc sulphate -100 ppm); T_3 (Copper sulphate -100 ppm); T_4 (Ferrous sulphate-100 ppm); T_5 (Calcium Nitrate-100 ppm); T_6 (Ammonium molybdate-50 ppm); T_7 (Mixture of all the micrunutrient-100 ppm); T_8 (Mixture of all without B- 100 ppm); T_9 (Mixture of all without Zn-100 ppm); T_{10} (Mixture of all without Mo-100 ppm); T_{11} (Mixture of all without Cu-100 ppm); T_{12} (Mixture of all without Fe-100 ppm); T_{13} (Mixture of all without Ca-100 ppm) and T_{14} (Commercial formulation (Multiplex)-4ml/lit). Characters studied are given in table 1 below. Analysis of Variance was worked out using Fisher and Yates (1967).

Table 1: Details of characters studied with methodologies used.

Parameter	Measurement Method / Unit
Plant height (cm) [90 DAT]	Measured from ground level to tip of the main stem (cm)
Number of branches on main stem	Counted manually at 90 DAT
Number of fruits per plant	Counted manually per plant
Fruit length (cm)	Measured using vernier callipers/ruler (cm)
Fruit diameter (cm)	Measured at widest part of fruit (cm)
Average fruit weight (g)	Weight of fruits measured on electronic balance (g)
Fruit yield (kg/250 m^2)	Total weight of fruits harvested per 250 m^2 plot area

Results and Discussion

Growth parameters

The results regarding the effect of foliar application of micronutrient on growth parameters of tomato are presented in table 2. Notably, the measurements of plant height at 90 days after transplanting (DAT) revealed significant variations based on the different micronutrients applied during both years of observation. Among the different treatments applied, T_{14} (Commercial formulation (Multiplex)-4ml/lit) showed maximum plant height 179.43, 182.75 and 181.09 cm followed by T_7(Mixture of all the micrunutrient-100 ppm) 178.82, 181.96 and 180.39 cm in both year 2023-24, 2024-25 and pooled respectively. However, minimum plant height 173.32, 176.42 and 174.87 cm was observed in T_0 (Control). Among the various treatments evaluated, T_{14} (Commercial formulation (Multiplex)-4ml/lit) demonstrated the highest number of branches on main stem, with measurements of 15.33, 15.67 and 15.50 branches. This was closely followed by T_7 (Mixture of all the micronutrients-100 ppm), which recorded 14.67, 15.33 and 15.00 branches for the years 2023-24, 2024-25, and the pooled mean, respectively. Conversely, the lowest number of branches on main stem was noted in T_0 (Control), with values of 9.67, 8.33 and 9.00 branches. The superiority of T_{14} (Commercial formulation, Multiplex-4 ml/lit) over other treatments may be attributed to its balanced and readily available supply of essential micronutrients in chelated forms, ensuring efficient absorption and translocation within the plant system. This optimum nutrient availability promotes vigorous vegetative growth, resulting in greater plant height and more branches on the main stem. On the other hand, the significantly lower performance of the control (T_0) highlights the deficiency of essential micronutrients in soil, resulting in restricted growth, fewer branches, and reduced chlorophyll content. These findings reinforce the role of balanced micronutrient application in improving plant vigour, photosynthetic efficiency, and overall growth performance. Polara *et al.* (2017) demonstrated the cost-effective enhancement of okra yields using a multi-micronutrient mixture applied via soil or foliar spray. Similarly, Ramesh *et al.* (2019) reported improved potato yields through the combined foliar application of Mg, S, Zn, and B, highlighting the significant role of secondary and micronutrients in optimizing crop productivity across different cropping systems. Similar findings were reported by Rajkumar *et al.* (2023) for micronutrient applications in French bean.

Yield parameters

Number of fruits per plant, Fruit length, fruit diameter, fruit weight and yield

The results regarding the effect offoliar application of micronutrient on yield parameters in tomato plants are presented in Table 3. Among the evaluated treatments, T_{14} (Commercial formulation, Multiplex, at 4 ml/lit) achieved the highest fruit count per plant, with 36.67, 36.00, and 36.33 fruits recorded for the years 2023-24, 2024-25, and the pooled mean, respectively. This was closely followed by T_7 (Mixture of all micronutrients at 100 ppm), which recorded 34.67, 34.00, and 34.33 fruits for the corresponding years. In contrast, the control treatment, T_0, recorded the lowest fruit count, with 21.67, 21.00, and 21.33 fruits during the same period. Among the treatments assessed, T_{14} (Commercial formulation (Multiplex)-4ml/lit) recorded maximum fruit length, with measurements of 4.67, 5.18 and 4.93 cm. T_7 (Mixture of all the micronutrients-100 ppm), at par recorded length of 4.47, 5.01 and 4.74 cm for the years 2023-24, 2024-25, and the pooled mean, respectively. In contrast, the control group, T_0, exhibited the minimum fruit length, with measurements of 3.21, 3.21 and 3.21 cm. Among the treatments evaluated, T_{14} (Commercial formulation (Multiplex)-4ml/lit) achieved the largest fruit diameter, measuring 5.26, 5.69, and 5.48 cm. Meanwhile, T_7 (Mixture of all the micronutrients-100 ppm) recorded comparable diameters of 5.13, 4.97, and 5.05 cm for the years 2023-24, 2024-25, and the pooled mean, respectively. In contrast, the control group, T_0, displayed the smallest fruit diameter, with measurements of 2.29, 2.43, and 2.36 cm. Among the treatments assessed, T_{14} (Commercial formulation (Multiplex)-4ml/lit) recorded the highest fruit weight, with measurements of 66.49, 67.87, and 67.18 grams. In comparison, T_7 (Mixture of all the micronutrients-100 ppm) showed similar fruit weights of 65.19, 65.69, and 65.44 grams for the years 2023-24, 2024-25, and the pooled mean, respectively. Conversely, the control group, T_0, exhibited the lowest fruit weight, with values of 55.28, 54.48, and 54.88 grams. Among the treatments evaluated, T_{14} (Commercial formulation (Multiplex)-4ml/lit) achieved the highest fruit yield in the 250 m^2 area, with recorded values of 33.24, 33.32, and 33.28 tonnes. T_7 (Mixture of all the micronutrients-100 ppm) demonstrated comparable fruit yields in the same area, with figures of 30.82, 30.46, and 30.64 tonnes for the years 2023-24, 2024-25, and the pooled mean, respectively. In contrast, the control group, T_0, yielded the lowest results in the 250 m^2 area, with values of 16.33, 15.61, and 15.97 tonnes.

The superior performance of T_{14} (Commercial formulation, Multiplex-4 ml/lit) across vegetative and reproductive parameters can be attributed to its balanced and readily available supply of essential micronutrients in chelated form, which ensured efficient uptake, translocation, and utilization by plants. The enhanced plant height, greater number of branches and higher chlorophyll content under T_{14} clearly reflect improved vegetative growth and photosynthetic efficiency, creating a stronger physiological base for higher productivity. Micronutrients such as Fe, Mn, Zn, and Cu are directly involved in chlorophyll synthesis, enzymatic activation, and hormonal regulation, which collectively accelerated metabolic activity. This also explains the earliness to first marketable harvest observed in T_{14}, as better nutrient availability promoted early flowering, synchronized fruit set, and faster crop maturity. Reproductive traits including fruit count, length, diameter, and weight were maximized in T_{14}, highlighting the role of micronutrients in pollen viability, stigma receptivity, cell division, and assimilate partitioning towards developing fruits. Consequently, the treatment achieved the highest yield per unit area, outperforming all others. Although T_7 (mixture of all micronutrients-100 ppm) also improved growth and yield parameters, the standardized formulation in T_{14} provided a more balanced ratio, resulting in superior performance. In contrast, the poor results under control (T_0) confirm the adverse effect of micronutrient deficiencies on growth, reproduction, and yield. Kumari and Sarika (2021) demonstrated better fruit weight in tomatoes on application of combination of ($ZnSO_4$ + B_3HO_3 + $CuSO_4$ + $FeSO_4$ at 600 ppm). While Akanksha *et al.* (2022) concluded that applying combination of all micronutrients at 100 ppm gave superior performance compared to the other treatments regarding yield and its contributing factors for cherry tomatoes. Bharti and Deepanshu (2023) similarly observed that combining $FeSO_4$ and $ZnSO_4$ outperformed their individual applications in improving tomato yield. Meanwhile, Lim *et al.* (2024) highlighted that a blend of calcium carbonate, calcium nitrate, calcium phosphate, calcium boron, zinc nitrate, and iron and calcium sulphatenot only enhanced fruit quality but also reduced blossom-end rot incidence, ultimately boosting overall tomato production.

Conclusions

The study evaluated the effect of different micronutrients applied in tomato on growth and yield traits over 2023-24, 2024-25. T_{14} (Commercial formulation, Multiplex, 4 ml/l) consistently outperformed other treatments, achieving the highest values across most parameters. Pooled mean performance for plant height (181.09 cm), number of branches (15.50 branches), chlorophyll content (48.88 mg/100g), fruit length of 4.93 cm, fruit diameter of 5.48 cm, fruit weight, measuring 67.18 grams, fruit yield per plant (7.49 kg), and fruit yield per 250 m^2 (33.28 tonnes).

Table 2: Effect of Foliar Application of micronutrients on growth parameters of tomato.

	Treatment Details	Plant height (cm) [90 DAT]			No of branches on main stem			Number of fruits per plant		
		2023-24	**2024-25**	**Pooled**	**2023-24**	**2024-25**	**Pooled**	**2023-24**	**2024-25**	**Pooled**
T_0	Control	173.32	176.42	174.87	9.67	8.33	9.00	21.67	21.00	21.33
T_1	Boric acid- 100 ppm	174.75	179.95	177.35	11.33	9.33	10.33	28.33	24.67	26.50
T_2	Zinc sulphate -100 ppm	176.73	179.31	178.02	10.33	11.67	11.00	29.00	28.67	28.83
T_3	Copper sulphate -100 ppm	176.97	181.10	179.03	9.67	11.33	10.50	25.67	28.00	26.83
T_4	Ferrous sulphate-100 ppm	176.99	177.65	177.32	11.33	11.00	11.17	27.33	29.33	28.33
T_5	Calcium Nitrate-100 ppm	177.61	178.55	178.08	11.00	11.67	11.33	31.33	28.67	30.00
T_6	Ammonium molybdate-50 ppm	178.12	178.31	178.22	11.67	12.00	11.83	32.67	29.67	31.17
T_7	Mixture of all the micrunutrient-100 ppm	178.82	181.96	180.39	14.67	15.33	15.00	34.67	34.00	34.33
T_8	Mixture of all without B- 100 ppm	177.53	181.00	179.26	12.33	13.67	13.00	28.33	29.33	28.83
T_9	Mixture of all without Zn-100 ppm	176.97	180.18	178.57	11.67	13.67	12.67	30.67	29.00	29.83
T_{10}	Mixture of all without Mo-100 ppm	175.90	178.39	177.15	13.00	14.00	13.50	33.00	33.33	33.17
T_{11}	Mixture of all without Cu-100 ppm	177.42	177.68	177.55	12.67	13.67	13.17	32.67	33.33	33.00
T_{12}	Mixture of all without Fe-100 ppm	177.67	178.27	177.97	14.00	13.00	13.50	29.00	33.67	31.33
T_{13}	Mixture of all without Ca-100 ppm	177.35	181.04	179.20	11.67	13.67	12.67	30.67	32.33	31.50
T_{14}	Commercial formulation (Multiplex)-4ml/lit	179.43	182.75	181.09	15.33	15.67	15.50	36.67	36.00	36.33
	SE. m (±)	**0.52**	**0.69**	**0.50**	**0.61**	**0.77**	**0.45**	**0.46**	**0.67**	**0.43**
	$CD_{0.05}$	**1.52**	**1.99**	**1.44**	**1.78**	**2.23**	**1.30**	**1.34**	**1.93**	**1.25**

Table 3: Effect of Foliar Application of micronutrients on number of fruits per plant, days to first marketable harvest and fruit length of tomato.

	Treatment Details	Fruit length (cm)			Fruit diameter (cm)			Fruit weight (g)			Fruit yield in 250 m^2 (tonnes)		
		2023-24	**2024-25**	**Pooled**	**2023-24**	**2024-25**	**Pooled**	**2023-24**	**2024-25**	**Pooled**	**2023-24**	**2024-25**	**Pooled**
T_0	Control	3.21	3.21	3.21	2.29	2.43	2.36	55.28	54.48	54.88	16.33	15.61	15.97
T_1	Boric acid- 100 ppm	3.47	4.12	3.80	3.31	3.78	3.54	56.31	57.79	57.05	21.75	19.44	20.59
T_2	Zinc sulphate -100 ppm	3.76	4.22	3.99	4.05	4.63	4.34	57.47	59.54	58.51	22.73	23.26	23.00
T_3	Copper sulphate -100 ppm	4.02	3.70	3.86	4.45	5.09	4.77	58.80	60.28	59.54	20.58	23.00	21.79
T_4	Ferrous sulphate-100 ppm	4.42	3.43	3.93	3.56	4.06	3.81	57.89	58.78	58.33	21.54	23.50	22.52
T_5	Calcium Nitrate-100 ppm	3.31	4.46	3.89	2.59	4.11	3.35	57.82	58.76	58.29	24.71	22.97	23.84
T_6	Ammonium molybdate-50 ppm	4.21	4.05	4.13	2.34	4.27	3.31	61.24	61.53	61.39	27.28	24.89	26.08
T_7	Mixture of all the micrunutrient-100 ppm	4.47	5.01	4.74	5.13	4.97	5.05	65.19	65.69	65.44	30.82	30.46	30.64
T_8	Mixture of all without B- 100 ppm	4.28	4.06	4.17	4.51	4.55	4.53	63.51	60.88	62.20	24.53	24.35	24.44
T_9	Mixture of all without Zn-100 ppm	3.17	3.71	3.44	3.36	3.84	3.60	60.94	63.38	62.16	25.49	25.07	25.28
T_{10}	Mixture of all without Mo-100 ppm	4.70	3.75	4.23	4.31	4.93	4.62	62.58	58.83	60.71	28.16	26.76	27.46
T_{11}	Mixture of all without Cu-100 ppm	3.35	4.31	3.83	4.91	5.62	5.26	63.93	63.58	63.75	28.48	28.89	28.68
T_{12}	Mixture of all without Fe-100 ppm	4.28	4.47	4.38	4.07	4.65	4.36	62.47	63.56	63.01	24.70	29.18	26.94
T_{13}	Mixture of all without Ca-100 ppm	4.32	4.64	4.48	5.03	5.18	5.11	57.41	64.58	61.00	24.00	28.47	26.24
T_{14}	Commercial formulation (Multiplex)-4ml/lit	4.67	5.18	4.93	5.26	5.69	5.48	66.49	67.87	67.18	33.24	33.32	33.28
	SE. m (±)	**0.08**	**0.16**	**0.09**	**0.13**	**0.22**	**0.14**	**0.56**	**0.73**	**0.50**	**0.43**	**0.62**	**0.38**
	$CD_{0.05}$	**0.22**	**0.46**	**0.26**	**0.38**	**0.65**	**0.42**	**1.62**	**2.11**	**1.45**	**1.61**	**1.81**	**1.11**

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