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Effect of Combined Micronutrients on Growth Yield and Quality of Tomato (*Solanum Lycopersicum* L.) var. Pusa Gaurav

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An investigation was undertaken to study the influence of combined micronutrients on the growth, yield, and quality of tomato (*Solanum lycopersicum* L.) var. Pusa Gaurav during the Rabi season of 2024–2025 at the Horticulture Research Farm, Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur (U.P.). The results indicated that the treatment T_1: $FeSO_4$ 50

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ppm + Boric Acid 100 ppm recorded the earliest 50% flowering (26.22 days), maximum plant height (51.68 cm, 82.90 cm, and 120.59 cm at successive growth stages), and the highest number of branches per plant (3.74, 8.07, and 14.99). It also recorded the maximum number of flowers per cluster (6.70), clusters per plant (6.13), minimum days to first fruit set (50.93), and earliest fruit picking (57.17 days). Furthermore, this treatment showed the highest number of fruits per cluster (6.17), fruits per plant (37.84), average fruit weight (71.14 g), fruit length (5.29 cm), fruit width (6.33 cm), fruit yield per plant (2.692 kg), fruit yield per plot (32.302 kg), and fruit yield per hectare (996.980 q ha^{-1}). Regarding quality parameters, it recorded the highest total soluble solids (TSS) (5.163 °Brix) and ascorbic acid content (16.427 mg/100 g). Among all the treatments, T_1 also resulted in the highest net return and benefit-cost (B:C) ratio, outperforming the control treatment.

Keywords: Micronutrients; growth; yield; quality; tomato.

1. INTRODUCTION

"Tomato (*Lycopersicon esculentum* Mill., 2n = 24) is a commercially important crop grown worldwide, both for the fresh fruit market and the processed food industry. It ranks second in importance after potato in many countries" (Yadav et al., 2024). "Tomato is a self-pollinated crop, and the Peru–Ecuador region is considered its center of origin. It was introduced to India by the Portuguese" (Singh et al., 2021). Tomato is cultivated extensively across tropical and subtropical regions of the world.

"In India, tomato is grown over an area of 809.9 thousand hectares, with an annual production of 19.697 million metric tonnes and a productivity of 24.4 MT/ha" (Singh et al., 2021). "The leading tomato-producing countries globally include the USA, several European nations, Japan, and China. In India, tomato production was reported to be 21.00 million tonnes in recent estimates, compared to 20.55 million tonnes in the year 2019–20" (Anonymous, 2022). Tomato fruits are typically globular or ovoid and are consumed both raw and cooked. A large proportion of tomatoes is used in the manufacture of processed products such as soup, juice, ketchup, puree, paste, and powder. Tomato is widely appreciated for its high vitamin C content and its contribution to color, taste, and flavor in food. Green tomatoes are also used in the preparation of pickles and preserves.

"Tomato possesses significant medicinal value. Its pulp and juice are easily digestible, mildly aperient, promote gastric secretion, purify blood, and act as intestinal antiseptics. It also stimulates a sluggish liver and is beneficial in treating chronic dyspepsia" (Joshi & Kohli, 2006). "From a nutritional standpoint, 100 grams of tomato provides approximately 48 mg calcium, 27 mg ascorbic acid, 20 mg phosphorus, 3.6 g carbohydrates, 0.9 g proteins, 0.8 g fiber, 0.4 mg iron, 0.2 g fat, and 20 kilocalories of energy. It also contains essential pigments like β-carotene and lycopene. Lycopene, responsible for the red color of tomatoes, is particularly important for its antioxidant properties, known to support vascular health and prevent scurvy" (Ejaz et al., 2011). "Boron deficiency in fresh-market cherry tomatoes is a common issue that adversely affects yield and fruit quality" (Davis et al., 2003). "Foliar application of boron has been observed to significantly increase boron and potassium concentrations in fruits compared to untreated plants. This suggests that boron is translocated from leaves to fruits and is involved in the translocation of potassium within the plant" (Davis et al., 2003).

Additionally, enhanced uptake of calcium (Ca), magnesium (Mg), sodium (Na), zinc (Zn), and boron (B) with higher boron levels in the root zone has been reported (Smit & Combrink, 2004). Boron is absorbed by plants in the form of borate ions and is known to interact antagonistically with calcium, potassium, and other cations. This antagonism can, however, favor the absorption of calcium. Boron plays a significant role in nitrogen metabolism and in maintaining the oxidation–reduction balance within plant cells. Boron deficiency is typically characterized by browning and the appearance of hollow stems in tomato plants.

A recently explored aspect of boron nutrition in tomato involves its interaction with salinity and water stress. According to Ben-Gal and Shani, (2002, 2003), under conditions of simultaneous boron deficiency and salt or water stress, the extent of growth suppression is governed by the factor that imposes the most severe limitation. The effects are not additive; rather, a dominant-stress-factor model, based on the Liebig–

Sprengel law of the minimum, effectively describes the response of tomato to such combined stresses. Furthermore, Ben-Gal and Shani, (2002) found that the yield response of tomato to boron nutrition correlates more closely with boron concentration in the irrigation water and soil solution than with boron levels in plant tissue. According to Alpaslan and Gunes (2001), soil boron concentrations of 5 mg kg^{-1} or higher are likely to induce boron toxicity symptoms in tomato plants.

2. MATERIALS AND METHODS

The present investigation entitled "Effect of Combined Micronutrients on Growth, Yield, and Quality of Tomato (*Solanum lycopersicum* L.) var. Pusa Gaurav" was conducted during the Rabi season of 2024–2025 at the Horticulture Research Farm, Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur (U.P.). The experimental site is located approximately 25 km from the Kanpur district headquarters (Uttar Pradesh, 208024), situated at 20°16′ N latitude and 80°08′ E longitude, at an altitude of 180 meters above sea level, falling under the southwestern plains of Uttar Pradesh in the subtropical climatic zone. The site belongs to the alluvial belt of the Indo-Gangetic Central Plain Zone (Agro-Climatic Zone V). The region has a semi-arid climate, characterized by hot, dry summers and moderate to severe winters, with an average annual rainfall of 800 to 900 mm and a mean precipitation of approximately 818 mm.

The experimental field was properly leveled and equipped with suitable irrigation and drainage facilities. Before sowing, stubble and weeds from the previous crop were manually removed. The experiment aimed to evaluate the effect of combined micronutrients on the growth, yield, and quality of tomato var. Pusa Gaurav. Seedlings were procured from a certified nursery in Kanpur and transplanted on 15th November 2024 at a spacing of 60 × 45 cm.

The experiment was laid out in a Randomized Block Design (RBD) with ten treatments comprising different concentrations and combinations of micronutrients including $FeSO_4$, $ZnSO_4$, Boric Acid, and Chelated Iron (0.5%), each replicated three times. A total of seventeen parameters were recorded during the study, including: Growth parameters: Days to 50% flowering, plant height (cm), number of branches per plant. Flowering and fruiting parameters: Number of flowers per cluster, number of clusters per plant, days to first fruit set, days to first fruit picking Yield parameters: Number of fruits per cluster, number of fruits per plant, average fruit weight (g), fruit length (cm), fruit width (cm), fruit yield per plant (kg), fruit yield per plot (kg), and fruit yield per hectare (q ha^{-1}) Quality parameters: Total Soluble Solids (°Brix) and ascorbic acid content (mg/100 g of fruit pulp) The collected data on growth, yield, and quality parameters were subjected to statistical analysis using Fisher's method of analysis of variance (ANOVA) as outlined by Where the 'F' test was found to be significant, treatment means were compared using the Critical Difference (CD) at a 5% probability level.

3. RESULTS AND DISCUSSION

The results of different levels and combinations of micronutrients are presented in Table 1 and Table 2. The foliar application of micronutrients had a significant influence on various growth, yield, and quality parameters of tomato (*Solanum lycopersicum* L.) var. Pusa Gaurav.

3.1 Growth Attributes

There was a significant effect of foliar application of micronutrients on the days to 50% flowering. The minimum days to 50% flowering (26.22 days) were recorded in Treatment T_1: $FeSO_4$ 50 ppm + Boric Acid 100 ppm, followed by T_2: $FeSO_4$ 100 ppm + $ZnSO_4$ 0.2%, and T_4: $ZnSO_4$ 0.1%. The maximum days to 50% flowering (36.01 days) were observed in Control (T_0 – untreated). As per the ANOVA (Table 1), the calculated F value (15.974) was greater than the table value (2.456) at the 0.05 level of significance, indicating a statistically significant difference among treatments. This suggests that different micronutrient combinations significantly influenced the flowering time in tomato. Foliar application of micronutrients significantly influenced plant height and number of branches per plant at 30, 60, and 90 days after transplanting (DAT). The maximum plant height (51.68 cm, 82.90 cm, and 120.59 cm at 30, 60, and 90 DAT, respectively) was recorded in T_1: $FeSO_4$ 50 ppm + Boric Acid 100 ppm, which was statistically at par with T_2: $FeSO_4$ 100 ppm + $ZnSO_4$ 0.2%. The minimum plant height (35.04 cm, 56.11 cm, and 97.96 cm) was recorded in the Control (T_0). Similarly, the maximum number of branches per plant (3.74, 8.07, and 14.99 at 30, 60, and 90 DAT, respectively) was also recorded in T_1, followed by T_2 and T_3: $ZnSO_4$ 0.5%, which were statistically at par. The lowest

Table 1. Effect of Combined Micronutrients on Growth Yield and Quality of Tomato (*Solanum Lycopersicum* L.) Var. Pusa Gaurav

Treatment Notation	Treatments details	Days to 50% flowering	Plant height (cm)			No. of Branches per plant			No. of flower per cluster
			30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	
T0	Control	36.01	35.04	56.11	97.96	2.12	3.17	7.17	4.16
T1	FeSO4 50ppm + Boric Acid 100ppm	26.22	51.68	82.90	120.59	3.74	8.07	14.99	6.70
T2	FeSO4 100ppm + ZnS04 0.2%	28.85	49.99	79.84	118.77	3.39	7.67	13.96	6.54
T3	ZnS04 0.5%	31.55	47.33	75.77	114.50	3.37	7.05	12.63	5.65
T4	ZnS04 0.1%	29.78	47.21	77.32	114.38	3.46	6.66	12.94	5.74
T5	Boric Acid 50ppm	31.67	40.66	71.93	106.67	3.28	5.58	10.97	5.24
T6	Boric Acid 100ppm	31.54	42.11	73.49	112.29	3.25	6.17	11.89	5.40
T7	FeSO4 100ppm	32.47	41.43	74.10	112.84	3.15	6.34	10.82	5.44
T8	FeSO4 150ppm	33.48	42.04	71.62	108.74	3.24	6.43	10.91	5.47
T9	Chelated Iron 0.5%	32.12	42.42	70.80	110.71	3.18	6.37	12.18	5.34
	F-Test	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
	C.D. at 0.5%	**1.953**	**2.409**	**1.874**	**2.887**	**0.204**	**0.336**	**0.648**	**0.469**
	S.Ed. (+)	**0.930**	**1.147**	**0.892**	**1.374**	**0.097**	**0.160**	**0.309**	**0.223**

Table 2. Effect of Combined Micronutrients on Growth Yield and Quality of Tomato (*Solanum Lycopersicum* L.) Var. Pusa Gaurav

Treatment Notation	No. of cluster per plant	Days to first fruit set	Days to first fruit picking	No. of fruit per cluster	No. of fruit per plant	Average fruit weight(g)	Fruit length (cm)	Fruit width (cm)	Fruit yield per plant (kg)	Fruit per plot (kg)	Fruit yield (q ha-1)	TSS (0Brix)	Ascorbic acid content (mg/100g of fruit pulp)
T0	3.17	73.83	79.29	2.88	9.16	33.49	3.17	4.40	0.306	3.669	113.244	2.503	14.243
T1	6.13	50.93	57.17	6.17	37.84	71.14	5.29	6.33	2.692	32.302	996.980	5.163	16.427
T2	5.72	55.00	59.93	6.03	34.47	62.41	5.18	6.10	2.153	25.839	797.493	5.057	16.413
T3	4.74	53.41	61.63	5.11	24.23	56.19	4.29	5.44	1.361	16.338	504.251	4.370	16.373
T4	4.13	55.76	62.74	4.41	18.18	59.34	4.44	5.28	1.079	12.945	399.552	4.370	16.340
T5	4.19	56.18	61.96	4.50	18.89	49.93	3.83	5.49	0.942	11.308	349.005	3.997	15.400
T6	4.47	54.96	64.26	3.57	15.94	50.59	4.10	5.64	0.807	9.680	298.766	3.913	15.397
T7	4.49	55.34	62.73	4.65	20.91	46.00	4.11	5.16	0.964	11.568	357.045	4.103	14.663
T8	4.36	57.29	61.60	4.37	19.09	47.61	4.09	5.23	0.910	10.920	337.023	3.960	14.257
T9	4.23	56.44	61.89	3.37	14.23	43.15	3.97	5.23	0.614	7.371	227.513	3.923	15.313
	S	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
	0.363	**1.873**	**2.597**	**0.336**	**2.607**	**3.062**	**0.113**	**0.298**	**0.169**	**2.031**	**67.676**	**0.673**	**0.545**
	0.173	**0.892**	**1.236**	**0.160**	**1.241**	**1.457**	**0.054**	**0.142**	**0.081**	**0.967**	**29.833**	**0.320**	**0.260**

number of branches per plant (2.12, 3.17, and 7.27) was recorded in the Control (T_0). The significant increase in plant height and branching under T_1 might be attributed to the enhanced nutrient availability due to micronutrient spray, which likely improved the soil's physical and chemical properties, leading to vigorous vegetative growth. On the contrary, untreated control plots showed poor performance, possibly due to micronutrient deficiency. Similar findings were reported by Kumari and Kumari (2021) in tomato.

3.2 Yield Attributes

As shown in Table 2, micronutrient application significantly affected flowering and fruiting traits: The maximum number of flowers per cluster (6.70) was recorded in T_1, followed by T_2 (6.12), both being statistically at par. The minimum (4.16) was found in the Control (T_0). The maximum number of clusters per plant (6.13) was recorded in T_1, which was also statistically at par with T_2 (5.84). The minimum clusters per plant (3.17) were observed in T_0. The results confirm the significant impact of foliar-applied micronutrients on flowering traits in tomato, in agreement with the observations made by Day (2000). The minimum number of days to first fruit set (50.93 days) was recorded in Treatment T_1: $FeSO_4$ 50 ppm + Boric Acid 100 ppm, which was statistically at par with T_2: $FeSO_4$ 100 ppm + $ZnSO_4$ 0.2%. In contrast, the maximum days to first fruit set (73.83 days) were observed in the Control (T_0 – untreated). Similarly, the earliest fruit picking (57.17 days) was observed in T_1, whereas the latest fruit picking (79.29 days) occurred in the control treatment (T_0). Regarding number of fruits per cluster, the maximum (6.17) was again recorded in T_1, which was statistically at par with T_3: $ZnSO_4$ 0.5%. The minimum number of fruits per cluster (3.24) was observed in the control treatment (T_0). As evidenced by the ANOVA results (Table 1), the calculated F-value (89.483) was greater than the table value (2.456) at the 5% level of significance, confirming a significant effect of different micronutrient combinations on this parameter. The positive impact of micronutrient application on fruit set and yield parameters may be attributed to enhanced photosynthetic activity, increased production and accumulation of carbohydrates, and an overall improvement in vegetative growth and flower retention. These factors likely contributed to the increased number and size of fruits per plant. These findings are in agreement with the results of Singh and Tiwari (2013), Mishra et al. (2012), Patil et al. (2009), and Sathya et al. (2013), who also reported enhanced yield and yield-attributing traits in tomato with the application of micronutrients. The maximum number of fruits per plant (37.84) was also recorded in T_1: $FeSO_4$ 50 ppm + Boric Acid 100 ppm, which was statistically at par with T_2: $FeSO_4$ 100 ppm + $ZnSO_4$ 0.2%. The minimum number of fruits per plant (9.16) was recorded in the control treatment (T_0 – untreated), whereas the maximum number of fruits per plant (37.84) was observed in T_1: $FeSO_4$ 50 ppm + Boric Acid 100 ppm, which was statistically at par with T_2: $FeSO_4$ 100 ppm + $ZnSO_4$ 0.2%. The maximum average fruit weight (71.14 g) was also recorded in T_1, whereas the minimum (33.49 g) was found in the control (T_0). Similarly, the maximum fruit length (5.29 cm) and fruit width (6.33 cm) were recorded in T_1, both statistically at par with T_2, while the minimum length (3.17 cm) and width (4.40 cm) were recorded in T_0. Regarding yield, the maximum fruit yield per plant (2.692 kg) and per plot (32.302 kg) were recorded in T_1, which were significantly higher than other treatments and statistically at par with T_2. The minimum fruit yield per plant (0.306 kg) and per plot (3.669 kg) were recorded in the control treatment (T_0). As indicated in the ANOVA table, the calculated F-value (160.149) was higher than the table value (2.456) at a 5% significance level, confirming a significant treatment effect on fruit yield. The maximum fruit yield per hectare (996.980 q ha^{-1}) was achieved in T_1, while the minimum (113.244 q ha^{-1}) was observed in T_0. These results suggest that the foliar application of combined micronutrients significantly enhanced fruit yield. The improved dry matter accumulation and yield across treatments can be attributed to the increased photosynthetic activity, which enhances carbohydrate production, better flower and fruit retention, and overall vegetative growth. These outcomes are in agreement with findings reported by Swati et al. (2011), Yadav et al. (2018), and Solanki et al. (2018).

3.3 Quality Attributes

The maximum total soluble solids (TSS) (5.163 °Brix) were recorded in T_1: $FeSO_4$ 50 ppm + Boric Acid 100 ppm, which was statistically at par with T_3: $ZnSO_4$ 0.5%, T_4: $ZnSO_4$ 0.1%, and T_7: $FeSO_4$ 100 ppm. The minimum TSS (2.503 °Brix) was recorded in T_0. The calculated F-value (10.442) was greater than the table value (2.456) at the 5% level, indicating significant treatment effects on TSS. The highest ascorbic acid content (16.427 mg/100 g pulp) was observed in T_1, which was statistically at par with T_5: Boric Acid 50 ppm, T_6: Boric Acid 100 ppm, and T_9: Chelated Iron 0.5%. The lowest ascorbic acid content (14.242 mg/100 g) was recorded in the control (T_0). The improvement in ascorbic acid levels is attributed to the synthesis of metabolic intermediates promoting the production of its precursors. Similar trends were reported by Narayan et al. (2007), who noted that foliar application of micronutrients significantly enhanced ascorbic acid content in tomato fruits. They found zinc to have the greatest effect, followed by a combination of multiple micronutrients. Likewise, Salam et al. (2010) and Yadav et al. (2018) reported the efficacy of micronutrient sprays in increasing ascorbic acid levels in tomato. The increase in total soluble solids (TSS) due to foliar application, particularly with zinc, copper, and combined micronutrient treatments, is likely a consequence of improved photosynthetic efficiency, leading to greater sugar accumulation in the fruit. These findings are in consonance with the results of Yadav et al. (2018), who reported similar enhancements in TSS.

4. CONCLUSION

Based on the findings of the present investigation, it can be concluded that Treatment T_1: $FeSO_4$ 50 ppm + Boric Acid 100 ppm was found to be the most effective among all treatments in terms of improving the growth, yield, and quality parameters of tomato (*Solanum lycopersicum* L.) var. Pusa Gaurav. This treatment recorded the best performance for key attributes such as: Days to 50% flowering, Plant height (cm), Number of branches per plant, Number of flowers per cluster, Number of clusters per plant, Days to first fruit set, Days to first fruit picking, Number of fruits per cluster, Number of fruits per plant, Average fruit weight (g), Fruit length (cm), Fruit width (cm), Fruit yield per plant (kg), Fruit yield per plot (kg), Fruit yield per hectare (q ha^{-1}), Total soluble solids (°Brix), Ascorbic acid content (mg/100 g of pulp) Hence, the combined foliar application of $FeSO_4$ 50 ppm and Boric Acid 100 ppm can be recommended as a promising nutrient management practice for enhancing growth, yield, and fruit quality in tomato cultivation under similar agro-climatic conditions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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