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Impact of growth regulators and micronutrients on yield and its attributing traits in tomato (*Solanum lycopersicum* L.)

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Abstract

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops cultivated worldwide for its nutritional and economic value. The present investigation was conducted to evaluate the effect of plant growth regulators and micronutrients on growth, flowering, fruit yield, quality parameters, and economics of tomato cultivation. Different concentrations of growth regulators such as GA₃ and NAA along with micronutrients including zinc, boron, iron, and micronutrient mixtures were evaluated under field conditions using Randomized Complete Block Design (RCBD). The results indicated that foliar application of GA₃ combined with micronutrient mixture significantly improved vegetative growth, flowering, fruit setting, fruit size, average fruit weight, total soluble solids (TSS), and yield per plant. The treatment involving GA₃ @ 50 ppm along with micronutrient mixture @ 0.5% produced the highest fruit yield, better quality fruits, and maximum benefit-cost ratio. Enhanced physiological activities, improved nutrient uptake, and better flower retention due to plant growth regulators and micronutrients contributed to increased productivity. The study concluded that combined application of growth regulators and micronutrients is an effective strategy for improving tomato yield and profitability under subtropical conditions.

Keywords: Tomato, GA₃, NAA, micronutrients, zinc, boron, fruit yield, TSS, economics

Introduction

Tomato (*Solanum lycopersicum* L.) belongs to the family Solanaceae and is one of the most widely cultivated vegetable crops in the world. It is an important protective food rich in vitamins, minerals, and antioxidants such as lycopene. India ranks second in tomato production after China and tomato occupies a prominent position among vegetable crops cultivated in the country.

Tomato fruits are consumed in fresh as well as processed forms including ketchup, puree, soup, sauce, juice, paste, and powder. The crop is highly remunerative and contributes significantly to nutritional security and farmer income. The fruit contains appreciable quantities of vitamin A, vitamin C, calcium, phosphorus, and iron. Plant growth regulators (PGRs) play an important role in regulating physiological processes such as cell division, elongation, flowering, fruit setting, and ripening. Gibberellic acid (GA₃) and Naphthalene Acetic Acid (NAA) are commonly used growth regulators known to improve plant growth, flowering, and yield in tomato. Micronutrients such as zinc, boron, iron, copper, and manganese are equally important for proper plant growth and fruit development. Zinc plays a key role in enzyme activation and protein synthesis, whereas boron is essential for pollen germination, fruit setting, and translocation of sugars. Foliar application of micronutrients improves vegetative growth, photosynthesis, fruit quality, and overall productivity.

Materials and Methods

The present investigation was conducted during the *rabi* season at the Faculty of Agricultural Sciences and Allied Industries, Rama University, Kanpur, Uttar Pradesh. The experiment was laid out in a Randomized Block Design (RBD) with three replications. Twelve treatments were evaluated with a plot size of 8.1 m². The crop used was tomato variety Kashi Aman. The spacing

adopted was 60 cm × 45 cm. Different treatments comprising growth regulators and micronutrients were applied as foliar sprays at appropriate growth stages. Details of Treatments are- T₁: Control, T₂: Borax @ 0.2%, T₃: Zinc sulphate @ 0.5%, T₄: Micronutrient mixture @ 0.5%, T₅: NAA @ 50 ppm, T₆: NAA @ 50 ppm + Borax @ 0.2%, T₇: NAA @ 50 ppm + Zinc sulphate @ 0.5%, T₈: NAA @ 50 ppm + Micronutrient mixture @ 0.5%, T₉: GA₃ @ 50 ppm, T₁₀: GA₃ @ 50 ppm + Borax @ 0.2%, T₁₁: GA₃ @ 50 ppm + Zinc sulphate @ 0.5%, T₁₂: GA₃ @ 50 ppm + Micronutrient mixture @ 0.5%.

Results and Discussion

Growth Parameters

Application of GA₃ along with micronutrient mixture significantly increased plant height and number of branches per

plant. The maximum plant height (96.42 cm) and number of branches (13.24) at harvest were recorded in T₈ (GA₃ @ 50 ppm + micronutrient mixture @ 0.5%). This enhanced vegetative growth can be attributed to increased cell elongation, improved nutrient absorption, and higher photosynthetic activity induced by the synergistic effect of GA₃ and micronutrients.

These findings are in agreement with Uddain *et al.* (2009) ^[1], who reported that GA₃ @ 30 ppm significantly increased plant height and number of branches in tomato. Similarly, Jakhar *et al.* (2018) ^[3] observed maximum vegetative growth with GA₃ @ 50 ppm. Prasad *et al.* (2013) ^[2] also reported significant improvement in growth attributes with GA₃ application. The role of micronutrients in enhancing cell division and enzyme activity further supports the superior performance of combined treatments.

Table 1: Effect of Growth Regulators and Micronutrients on Plant Height (cm)

Treatment	30 DAT	60 DAT	90 DAT	At Harvest
T ₀	24.35	48.26	62.48	65.22
T ₁	28.42	58.63	76.40	79.35
T ₂	27.18	55.74	73.25	76.10
T ₃	26.32	53.40	70.36	73.44
T ₄	26.85	54.62	71.58	74.96
T ₅	29.40	61.72	80.48	84.11
T ₆	31.26	66.45	84.72	88.43
T ₇	32.14	68.10	86.55	90.30
T ₈	34.65	72.84	92.18	96.42
T ₉	30.22	64.18	82.26	85.40
T ₁₀	31.06	65.44	83.65	87.32
T ₁₁	33.40	70.32	89.44	93.28
SEm±	0.62	1.14	1.32	1.40
CD at 5%	1.82	3.34	3.86	4.10

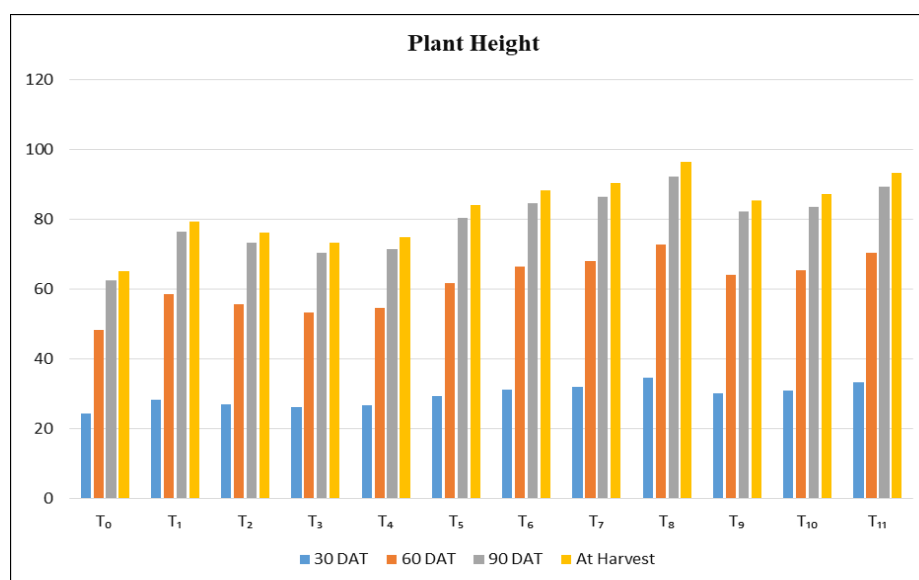


Fig 1: Plant Height

Table 2: Effect on Number of Branches per Plant

Treatment	30 DAT	60 DAT	90 DAT
T ₀	3.22	5.18	7.12
T ₁	4.10	6.84	9.64
T ₂	3.98	6.42	9.20
T ₃	3.84	6.18	8.88
T ₄	3.90	6.26	9.04
T ₅	4.42	7.10	10.42
T ₆	4.85	7.82	11.36

T ₇	5.10	8.18	11.88
T ₈	5.64	8.96	13.24
T ₉	4.72	7.56	10.98
T ₁₀	4.90	7.84	11.26
T ₁₁	5.36	8.62	12.74
SEm±	0.12	0.22	0.34
CD at 5%	0.35	0.64	0.98

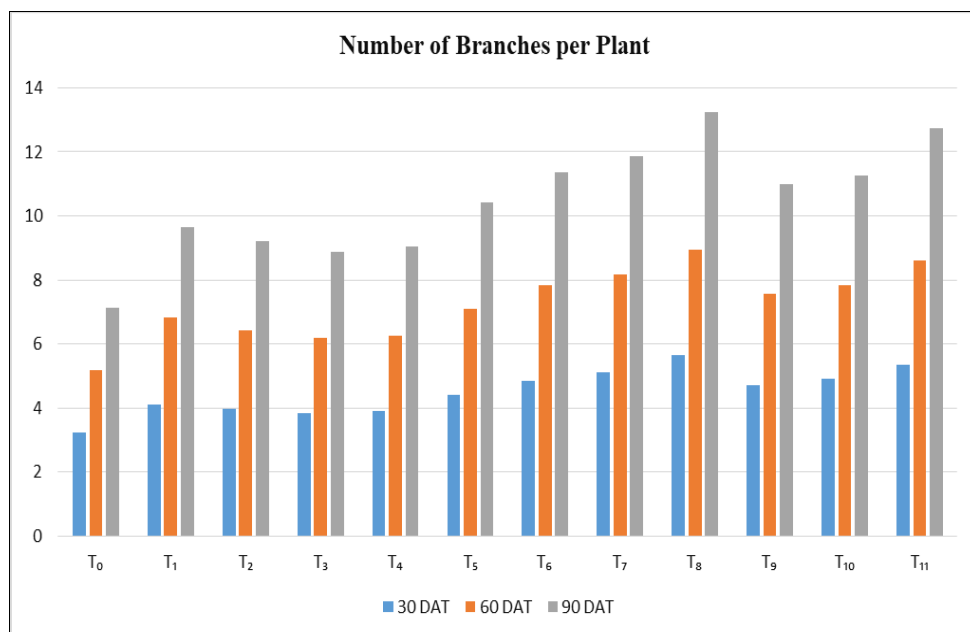


Fig 2: Number of Branches plant

Flowering Parameters

The earliest days to first flowering (30.42) and 50% flowering (37.88) were recorded in T₈. This reduction in days to flowering may be due to hormonal balance and enhanced metabolic activities triggered by GA₃ and micronutrients.

These results are supported by the findings of Kushwaha *et al.* (2025) and Jakhar *et al.* (2018) [3, 6], who reported earlier flowering with GA₃ application. The positive effect of boron and zinc on reproductive development further justifies the superior performance of combined treatments.

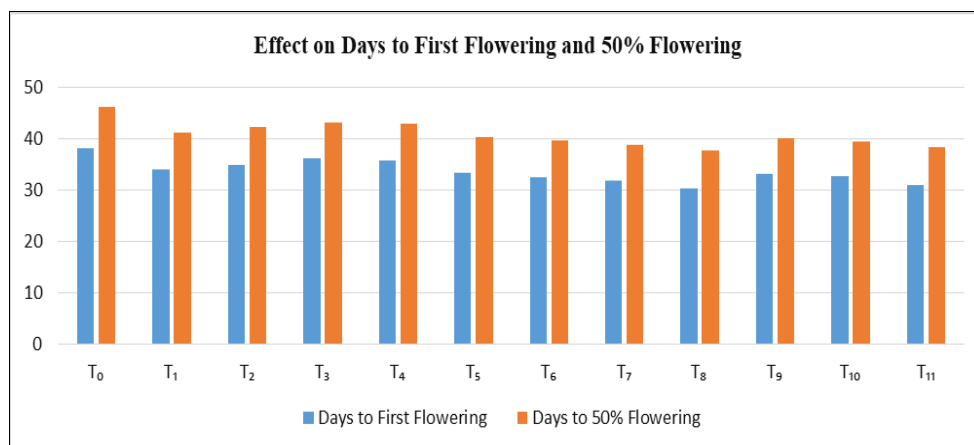
Table 3: Effect on Days to First Flowering and 50% Flowering

Treatment	Days to First Flowering	Days to 50% Flowering
T ₀	38.24	46.35
T ₁	34.18	41.20
T ₂	35.06	42.44
T ₃	36.22	43.18
T ₄	35.84	42.98
T ₅	33.48	40.36
T ₆	32.62	39.74
T ₇	31.94	38.96
T ₈	30.42	37.88
T ₉	33.14	40.12
T ₁₀	32.80	39.62
T ₁₁	31.10	38.42
SEm±	0.42	0.56
CD at 5%	1.22	1.64

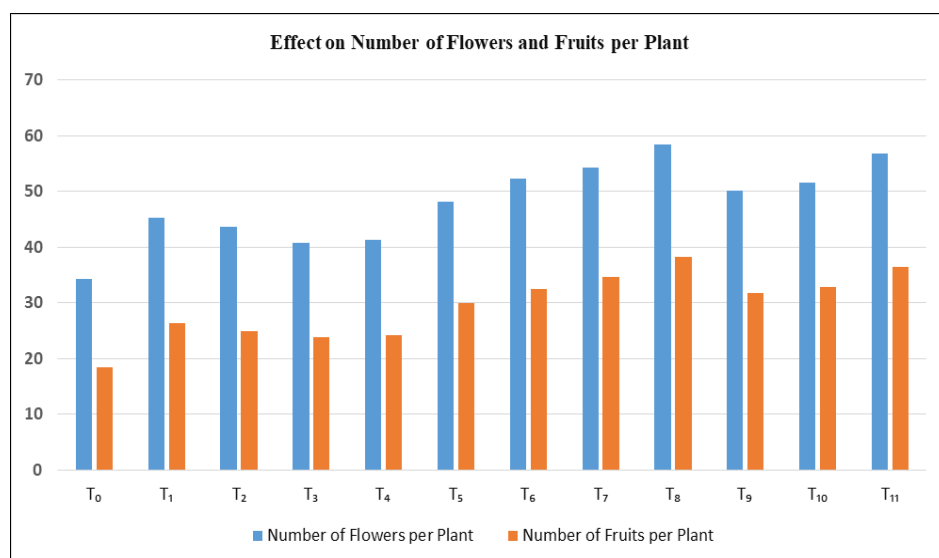
Yield Attributes

Maximum number of flowers (58.44) and fruits per plant (38.26), along with highest fruit length (6.18 cm) and diameter (5.86 cm) were observed in T₈. Improved fruit setting and reduced flower drop were mainly responsible for higher yield

attributes. This is in conformity with the findings of Ali *et al.* (2015) and Meena *et al.* (2015) [4, 5], who reported significant improvement in fruit number and size with combined application of zinc and boron. Prasad *et al.* (2013) [2] also documented enhanced yield attributes with GA₃ @ 80 ppm.

**Fig 3:** effect on days to first flowering and 50% flowering**Table 4:** Effect on Number of Flowers and Fruits per Plant

Treatment	Number of Flowers per Plant	Number of Fruits per Plant
T ₀	34.22	18.44
T ₁	45.18	26.36
T ₂	43.64	24.88
T ₃	40.82	23.74
T ₄	41.28	24.10
T ₅	48.10	29.84
T ₆	52.34	32.48
T ₇	54.20	34.62
T ₈	58.44	38.26
T ₉	50.18	31.72
T ₁₀	51.46	32.84
T ₁₁	56.72	36.44
SEm±	1.12	0.88
CD at 5%	3.28	2.58

**Fig 4:** effect on number of flowers and fruits per plant**Table 5:** Effect on Fruit Length and Fruit Diameter

Treatment	Fruit Length (cm)	Fruit Diameter (cm)
T ₀	4.18	3.92
T ₁	5.24	4.86
T ₂	5.10	4.72
T ₃	4.92	4.54
T ₄	4.98	4.62
T ₅	5.48	5.12
T ₆	5.76	5.44
T ₇	5.92	5.60

T ₈	6.18	5.86
T ₉	5.62	5.28
T ₁₀	5.70	5.34
T ₁₁	6.02	5.74
SEm±	0.10	0.08
CD at 5%	0.30	0.24

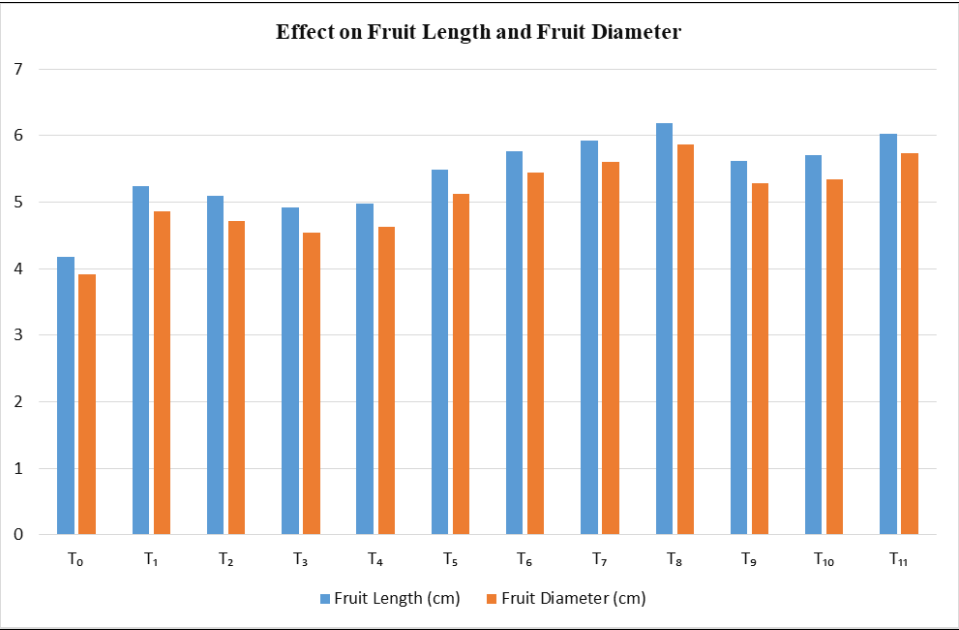


Fig 5: Effect on fruit length and fruit diameter

Fruit Yield

The highest average fruit weight (102.64 g), yield per plant (2.96 kg), and yield per hectare (632.76 q/ha) were recorded in T₈. The synergistic effect of GA₃ and micronutrients improved nutrient use efficiency and assimilate partitioning towards fruits.

These results are strongly supported by Kushwaha *et al.* (2025)^[6], who reported maximum yield with GA₃ @ 50 ppm + micronutrient mixture. Similar findings were documented by Jakhar *et al.* (2018) and Ali *et al.* (2015)^[3, 4].

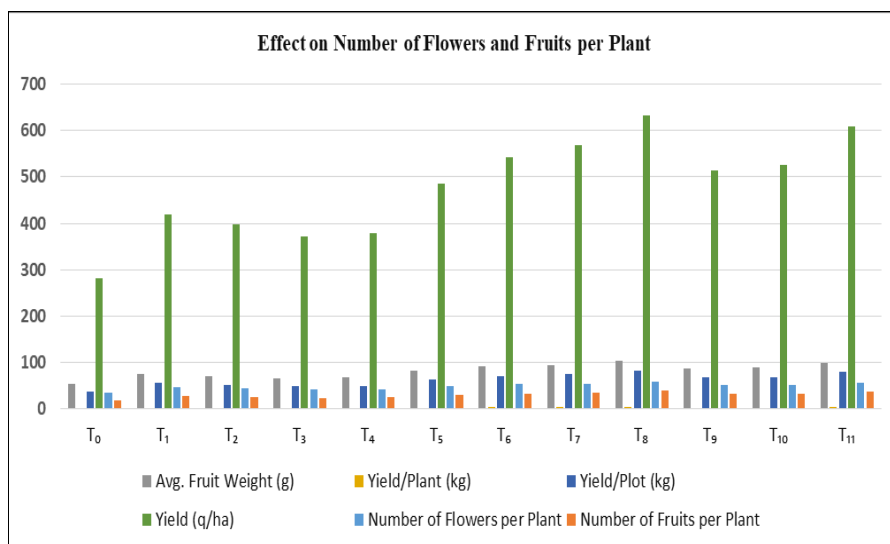
Table 6: Effect on Average Fruit Weight and Yield

Treatment	Avg. Fruit Weight (g)	Yield/Plant (kg)	Yield/Plot (kg)	Yield (q/ha)
T ₀	52.40	1.24	36.40	282.12
T ₁	74.22	1.94	54.82	418.36
T ₂	70.48	1.82	51.36	396.48
T ₃	66.18	1.70	48.44	372.26
T ₄	67.44	1.74	49.10	378.54
T ₅	82.26	2.22	63.42	486.36
T ₆	90.84	2.48	70.66	542.18
T ₇	94.42	2.62	74.18	568.32
T ₈	102.64	2.96	82.44	632.76
T ₉	86.54	2.34	67.18	514.44
T ₁₀	88.72	2.40	68.82	526.18
T ₁₁	98.16	2.82	79.12	608.54
SEm±	1.84	0.08	1.92	12.42
CD at 5%	5.38	0.24	5.62	36.24

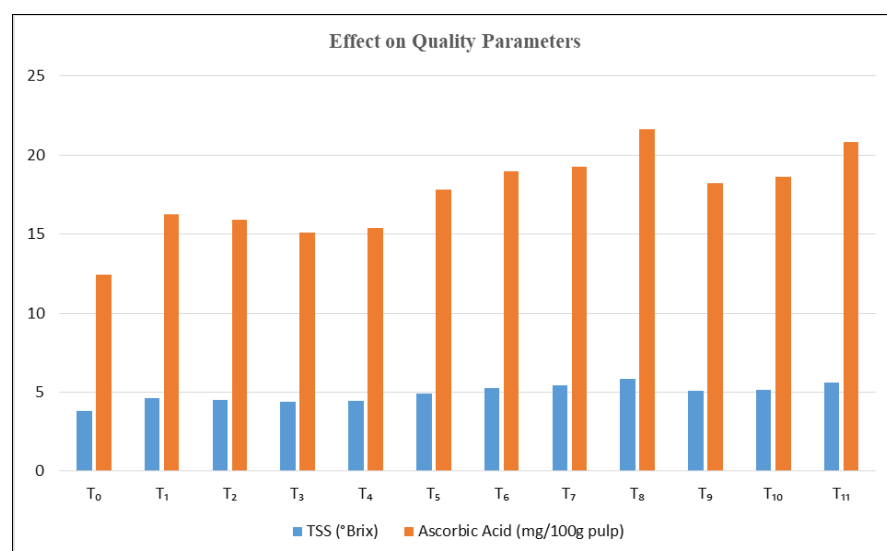
Quality Parameters

The highest TSS (5.84 °Brix) and ascorbic acid content (21.62 mg/100g) were recorded in T₈. Micronutrients like zinc and boron played a vital role in improving sugar accumulation and

metabolic activities in fruits.This corroborates the findings of Kushwaha *et al.* (2025) and Pandey *et al.* (2022)^[6, 7], who observed improved fruit quality with combined application of GA₃ and micronutrients.

**Fig 6:** Effect on number of flowers and fruits per plant**Table 7:** Effect on Quality Parameters

Treatment	TSS (°Brix)	Ascorbic Acid (mg/100g pulp)
T ₀	3.82	12.42
T ₁	4.64	16.24
T ₂	4.52	15.88
T ₃	4.38	15.10
T ₄	4.44	15.36
T ₅	4.92	17.84
T ₆	5.26	18.96
T ₇	5.40	19.28
T ₈	5.84	21.62
T ₉	5.10	18.22
T ₁₀	5.16	18.64
T ₁₁	5.62	20.84
SEm±	0.08	0.42
CD at 5%	0.24	1.22

**Fig 7:** Effect on quality parameters

Economics

The maximum net return and benefit-cost ratio (3.45) were obtained from T₈, indicating the economic viability of this treatment for commercial cultivation.

Table 8: Economics of Different Treatments

Treatment	Cost of Cultivation (Rs./ha)	Gross Return (Rs./ha)	Net Return (Rs./ha)	B:C Ratio
T ₀	125000	282120	157120	1.25
T ₁	132000	418360	286360	2.16
T ₂	131500	396480	264980	2.01
T ₃	129800	372260	242460	1.87
T ₄	130200	378540	248340	1.91
T ₅	135000	486360	351360	2.60
T ₆	138400	542180	403780	2.92
T ₇	139200	568320	429120	3.08
T ₈	142000	632760	490760	3.45
T ₉	137200	514440	377240	2.75
T ₁₀	137800	526180	388380	2.82
T ₁₁	140600	608540	467940	3.33

Conclusion

The present investigation clearly demonstrated that foliar application of plant growth regulators and micronutrients significantly influenced growth, flowering, fruit yield, quality, and economics of tomato cultivation. Among the treatments, GA₃ @ 50 ppm combined with micronutrient mixture @ 0.5% proved most effective in improving plant growth, fruit yield, fruit quality, and profitability. Therefore, combined application of growth regulators and micronutrients may be recommended for commercial tomato cultivation to achieve higher productivity and better economic returns under subtropical conditions.

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