



Plant Archives

Journal homepage: <http://www.plantarchives.org>DOI Url : <https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.2.007>

MICRONUTRIENTS AND PLANT GROWTH REGULATORS: UNLOCKING TOMATO POTENTIAL FROM BUD TO BASKET (*SOLANUM LYCOPERSICUM* L.)

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(Date of Receiving-23-05-2025; Date of Acceptance-30-07-2025)

ABSTRACT

Tomato cultivation often grapples with nutrient deficiencies and erratic environmental conditions, necessitating sustainable interventions to boost productivity. This study investigates the impact of micronutrients and plant growth regulators (PGRs) on the growth, flowering, fruiting, and yield of tomato (*Solanum lycopersicum* L.). A field experiment was conducted during the Rabi season (2022–23) at the Horticulture Demonstration Farm, SGT University, using a Randomized Block Design with 11 treatments (including GA₃, NAA, ZnSO₄, boric acid, and FeSO₄ at varying concentrations) and three replications.

Results revealed that the application of PGRs and micronutrients significantly improved key growth and yield parameters. Notably, GA₃ at 100 ppm (T₂) emerged as the most effective treatment, promoting superior plant height, branching, flower clusters, and fruit attributes. It also accelerated phenological events like flowering and fruit set, and led to the highest fruit yield (799.03 q/ha), maximum net return (Rs. 12.69 lakhs/ha), and the best benefit-cost ratio (8.77). Enhanced TSS, shelf life, and ascorbic acid content further validated the quality benefits. This study underscores the promising role of GA₃ and other growth enhancers in optimizing tomato production, offering a viable pathway for higher profitability and sustainable farming

Key words: Tomato; Growth Yield; Micronutrients; PGR; Shelf Life; Randomized Block Design.

Introduction

“Tomato (*Solanum lycopersicum* L.) is an important vegetable of the Solanaceae family, with a chromosome number of $2n=2x=24$. It originates in the wild form in the Peru-Ecuador-Bolivia region of the Andes, South America” (Rick, 1969) and is grown in almost every corner of the world in outdoor fields, greenhouses, and net houses (Roberston and Labate, 2007). Its high nutritional value, versatility in culinary applications, and increasing demand have positioned it as a crucial component of daily diets and in the food processing industry (Giovannoni, 2007). “Tomatoes are universally known as a Protective Food. It is a versatile vegetable used for culinary purposes. Tomato is generally consumed as salad, cooked, or processed food. Unripe green fruits are used to make pickles and preserves and are consumed

after cooking as vegetables” (Kaur, 2004). Tomatoes are well-known for their flavour, and their soup can also be used as a laxative (Di-Mascio *et al.*, 1989). For its tremendous nutritional value, the tomato is commonly known as the poor man’s orange (Sudesh *et al.*, 2024; Dar *et al.*, 2012). “Tomato is a rich source of antioxidants (mainly lycopene and β -carotene), vitamin A, vitamin C, and minerals, such as Ca, P, and Fe (Isabel Odriozola-Serrano, 2008). Lycopene is a major antioxidant pigment, “which is responsible for the red color in tomatoes. Lycopene plays an important role in human health in reducing the risk of chronic diseases” (Di-Mascio, 1989). The cultivation of tomatoes faces several challenges, including nutrient deficiencies, fluctuating environmental conditions, and the need for sustainable agricultural practices to meet the increasing demand for nutritious

food (Wakeel *et al.*, 2018). India is the second largest tomato-producing country in the world, The production of tomatoes in 2022-23 was estimated at 21.5 million metric tons, the area under tomato crop in 2022-23 was estimated at 9.5 lakh hectares, (NHB, 2021). In India, tomatoes have a wider coverage than other vegetables. The major tomato-producing states are Andhra Pradesh, Madhya Pradesh, Karnataka Uttar Pradesh, Maharashtra, West Bengal, Orissa and Bihar. Andhra Pradesh is the leading state in the area as well as in production.

Micronutrients and plant growth regulators (PGRs) have emerged as potential tools for addressing these challenges and optimizing tomato growth, yield, and fruit quality (Wu, 2024). “Micronutrients are not only essential for better growth, yield, and quality but are also important, like other major nutrients, despite their requirement in micro quantities” (Xiao *et al.*, 2022). “They also help in the uptake of major nutrients and are vital to the growth of plants, acting as catalysts in promoting various organic reactions from cell development to respiration, photosynthesis, chlorophyll formation, enzyme activity, hormone synthesis, and nitrogen fixation”. (Arora, 1979) reported that micronutrients such as boron, copper, molybdenum, and zinc can also improve the vegetative growth, fruit set, and yield of tomatoes. “Plant growth regulators (PGRs) are extensively used in crop production to improve plant growth and yield by increasing fruit set, fruit number, and weight. They play a significant role in the development of tomato fruits” (Srivastava and Handa, 2005). “They help to reduce flower and fruit drops, improve production per unit area and time, and stimulate the translocation of photosynthates, leading to better retention of flowers and fruits” (Talvinder *et al.*, 2024;

Chaudhary *et al.*, 2006; Sreenivas *et al.*, 2017). “The use of plant growth regulators has improved the growth and yield of tomatoes and other vegetables, concerning better growth and yield” (Saha, 2009). GA3 is an important growth-stimulating hormone that enhances “cell division and elongation, thus helping in the growth and development of plants. GA3 increases leaf size, stem length, and fruit set” (Serrani, 2007).

Materials and Methods

The field experiment was conducted at Horticulture Demonstration Farm, SGT University, Gurugram, Haryana, during Rabi 2022-23. The climate of this region is typically semi-arid, with aridity and extreme temperature swings in the summer and winter. The temperature increases up to 46°C during May/June and as low as 15°C in the winter. The average annual rainfall of the area is 600 mm, which falls between July and September during the rainy season. Crop was cultivated under irrigated conditions, the soil type was sandy loam and slightly alkaline in nature with a soil pH of 7.7. Arka Samrat is a triple-resistant high-yielding FI hybrid developed by crossing IIHR-2835 X IIHR-2832. The tomato hybrid Arka Samrat is the first F1 Hybrid with triple disease resistance to tomato leaf curl disease (ToLCV), bacterial wilt (BW), and early blight. Tomato hybrid Arka Samrat fruits are oblate to round, large (90–110 g), deep red, and firm. Tomato hybrid seeds were procured from the Indian Institute of Horticulture Research (IIHR), Bengaluru, India. The experiment was conducted in a Randomized Block Design with 11 treatments. All treatments were replicated thrice. Seeds were sown in raised beds on October 17, 2022, whereas the seedlings were transplanted in the main field on November 25, 2022. Transplanting of 39 d old seedlings

Table 1: Effect of micronutrients and PGR on growth and flowering parameters of tomato.

Treatments	Plant height (cm)			No. of Branches ⁻¹			Days to 50 % flowering	No. of flower cluster ⁻¹	No. of cluster plant ⁻¹
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT			
T ₀ (Control)	35.56	60.23	95.30	3.03	5.60	9.67	36.80	4.93	4.20
T ₁ (GA ₃ @50ppm)	49.35	81.88	121.65	4.47	8.53	13.73	29.53	7.07	6.53
T ₂ (GA ₃ @100ppm)	52.40	85.27	135.11	5.13	9.00	14.93	27.67	8.33	7.13
T ₃ (NAA @50ppm)	49.55	80.89	111.62	4.93	7.47	12.87	29.53	6.40	5.93
T ₄ (NAA @100ppm)	51.12	79.85	117.38	4.13	7.73	13.40	29.87	6.87	6.60
T ₅ (ZnSO ₄ @0.5%)	42.16	74.54	102.23	3.93	6.67	11.53	31.60	5.93	5.67
T ₆ (ZnSO ₄ @1%)	45.45	79.38	110.55	3.87	7.13	12.53	31.87	6.47	5.87
T ₇ (Boric acid @50ppm)	38.08	71.81	105.94	3.27	7.07	11.47	31.73	6.53	6.13
T ₈ (Boric acid @100ppm)	40.93	75.81	111.97	3.73	6.73	11.27	33.40	6.60	6.07
T ₉ (FeSO ₄ @100ppm)	48.10	77.68	113.23	3.53	6.53	12.60	32.13	6.07	5.73
T ₁₀ (FeSO ₄ @150ppm)	48.63	65.53	110.06	3.60	6.27	12.47	31.33	6.20	5.53
S.Em ±	1.48	2.59	3.28	0.16	0.33	0.36	0.95	0.26	0.22
C.D. at 0.5%	4.37	7.65	9.68	0.48	0.97	1.06	2.79	0.78	0.66

was performed at 60×45 cm spacing after marking with a marker. FYM was applied at a rate of 25 t ha^{-1} , nitrogen at a rate of 120 kg ha^{-1} , potassium and phosphorus at a rate of 60 kg ha^{-1} . A full dose of FYM, P, K, and half doses of N were applied at the time of transplantation, and the remaining dose of nitrogen was applied in three equal splits at 20 days of intervals. Micronutrients ZnSO_4 @0.5%, ZnSO_4 @1%, boric acid @50 ppm, boric acid @100 ppm, FeSO_4 @100 ppm, FeSO_4 @150 ppm, and Plant Growth Regulators GA_3 at 50 ppm, GA_3 at 100 ppm, NAA at 50 ppm, and NAA at 100 ppm were sprayed with the help of a Kraft KK-PS1000 hand sprayer. Spraying was done at 30,45,60,75, and DAT. After transplanting, various intercultural operations, such as gap filling, hoeing, weeding, earthing up, irrigation pest, and disease control, were performed to improve the growth and development of the tomato. Irrigation was performed according to the requirement. Plant protection measures were undertaken as per the recommendations whenever as and when required. A total of 11 treatments using two different concentrations of each micronutrient, viz., ZnSO_4 , Boric acid, and FeSO_4 and growth regulators, viz., GAs, and NAA. Fourteen growth, flowering, fruiting, and yield parameters, viz., days to 50% flowering, plant height (cm), number of branches plant⁻¹, number of flower cluster⁻¹, number of cluster plant⁻¹, days to first fruit set, no. fruit per cluster⁻¹, no. fruit plant⁻¹, average fruit weight (g), fruit length (cm), fruit width (cm), fruit yield plant (kg), fruit yield plot⁻¹ (kg), and fruit yield (q ha⁻¹) of tomato were measured during the experiments from 2022 to 2023. Statistical analysis of the data was performed using the analysis of variance (ANOVA) technique of (Fisher 1950). Five plants from each plot were randomly selected and tagged to record the observations.

Results and Discussion

The growth and flowering parameters were significantly different among the treatments (Table 1). The application of micronutrients and plant growth regulators significantly increased growth parameters, such as plant height (cm), number of branches⁻¹, days to 50%

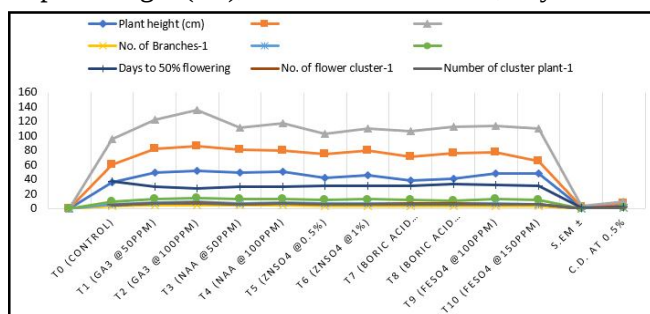


Fig. 1: Effect of micronutrients and PGR on growth and flowering parameters of tomato.

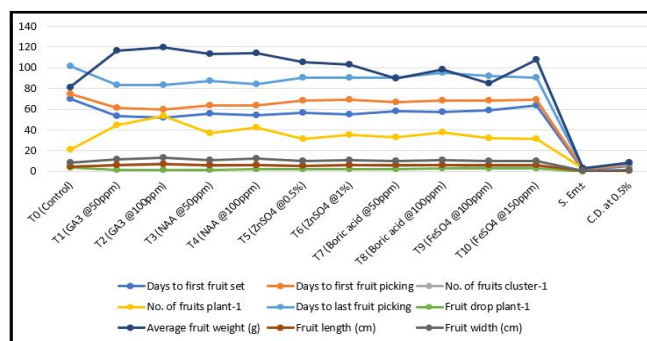


Fig. 2: Effect of micronutrients and PGR on fruiting parameters of tomato.

flowering, number of flower cluster⁻¹, and number of cluster plant⁻¹ of tomato. The combination of cytokinins and gibberellins was particularly effective in promoting both vegetative and reproductive growth, as reported by Navale *et al.*, (2010), who emphasized the need for a balanced application of PGRs for optimal growth and flowering. Statistical analysis of the data on plant height (cm), number of branches⁻¹, days to 50% flowering, number of flower cluster⁻¹, and number of cluster plant⁻¹ of tomato clusters was significant. The maximum plant height (52.40, 85.27, 135.11) (cm) at 30, 60, and 90 DAT was recorded in treatment T₂ (GA_3 at 100ppm). The minimum plant heights (35.56, 60.23, and 95.30) (cm) were found in the control T₀. The maximum number of branches plant⁻¹ (5.13, 9.00, 14.93) at 30, 60, and 90 DAT was recorded in the treatment T₂ (GA_3 at 100 ppm). The minimum number of branches plant⁻¹ (3.03, 5.60, 9.67) was found in control T₀. The minimum number of days to 50% flowering (27.67) was recorded in treatment T₂ (GA_3 at 100 ppm). The maximum number of days to 50% flowering (36.80) was found in the control T₀. The maximum number of flower cluster⁻¹ (8.33) was recorded in treatment T₂ (GA_3 at 100 ppm). The minimum number of flowers cluster⁻¹ (4.93) was found in the control T₀. The maximum number of cluster plant⁻¹ (7.13) was recorded for treatment T₂ (GA_3 at 100 ppm). The

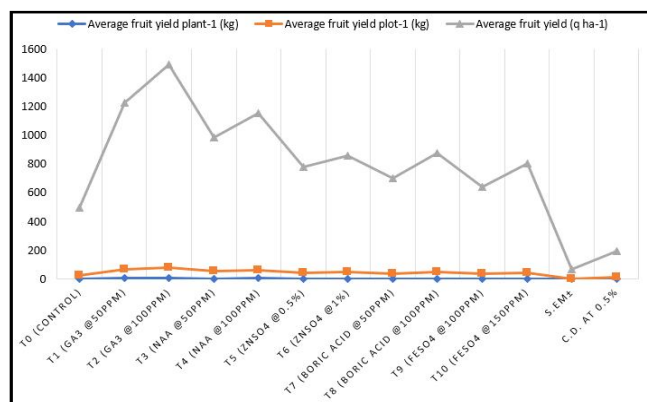


Fig. 3: Effect of micronutrients and PGR on yield parameters of Tomato.

Table 2: Effect of micronutrients and PGR on fruiting parameters of tomato.

Treatments	Days to first fruit set	Days to first fruit picking	No. of fruits cluster ⁻¹	No. of fruits plant ⁻¹	Days to last fruit picking	Fruit drop plant ⁻¹	Average fruit weight (g)	Fruit length (cm)	Fruit width (cm)
T ₀ (Control)	69.87	74.87	4.33	21.19	101.07	3.87	81.33	4.72	8.48
T ₁ (GA ₃ @50ppm)	53.53	61.40	6.00	44.53	83.43	1.40	116.13	6.29	11.95
T ₂ (GA ₃ @100ppm)	51.47	59.47	7.60	53.07	82.93	1.13	119.67	7.01	13.50
T ₃ (NAA @50ppm)	55.93	63.93	5.67	36.80	87.21	1.53	113.53	6.12	10.70
T ₄ (NAA @100ppm)	53.80	63.47	5.93	42.67	84.00	2.07	114.07	6.40	12.10
T ₅ (ZnSO ₄ @0.5%)	56.60	68.60	5.20	31.40	90.77	2.33	105.20	5.55	10.10
T ₆ (ZnSO ₄ @1%)	55.20	68.87	6.33	35.33	90.64	2.53	102.87	5.99	10.96
T ₇ (Boric acid @50ppm)	57.73	66.67	5.53	33.13	90.43	2.47	89.47	6.00	9.73
T ₈ (Boric acid @100ppm)	57.27	68.33	5.73	37.60	95.17	2.73	98.47	5.97	10.47
T ₉ (FeSO ₄ @100ppm)	59.13	68.20	4.87	31.93	92.20	2.67	84.53	5.91	10.03
T ₁₀ (FeSO ₄ @150ppm)	63.33	69.33	5.27	31.60	90.44	2.87	107.40	6.01	9.95
S.Em±	1.73	2.07	0.23	2.65	2.70	0.18	2.98	0.29	0.42
C.D. at 0.5%	5.11	6.12	0.67	7.86	7.95	0.53	8.78	0.84	1.25

minimum number of cluster plant⁻¹ (4.20) was found in the control T₀. Various fruiting parameters showed significant differences among the treatments. The application of micronutrients and plant growth regulators significantly increased the fruiting parameters, viz., days to first fruit set, days to first fruit picking, number of fruits per cluster, number of fruits plant⁻¹, days to last fruit picking, fruit drop per plant, average fruit weight (g), fruit length (cm), and fruit width (cm) of tomatoes. Gibberellins, well known for promoting flowering and fruit set, also had a positive effect on the tomato plants in this study. The application of gibberellins resulted in an earlier onset of flowering and an increased number of flowers per plant, which is consistent with the findings of Serrani *et al.*, (2021).

Statistical analysis of data on days to first fruit set, days to first fruit picking, number of fruits per cluster, number of fruits plant⁻¹, days to last fruit picking, fruit drop per plant, average fruit weight (g), fruit length (cm), and fruit width (cm) of tomatoes was significant (Zhang *et al.*, 2021). The minimum number of days to the first fruit set (51.47) was recorded for treatment T₂ (GA₃ at 100 ppm). The maximum number of days to the first fruit set (69.87) was found in the control T₀. The minimum number of days to first fruit picking (59.47) was recorded for treatment T₂ (GA₃ at 100 ppm). The maximum number of days to first fruit picking (74.87) was observed in the control T₀. The maximum number of fruits per cluster (7.60) was recorded for treatment T₂ (GA₃ at 100 ppm). The minimum number of fruits per cluster (4.33) was observed in the control T₀. The maximum number of fruits plant⁻¹ (53.07) was recorded for treatment T₂ (GA₃ at 100ppm). The minimum number of fruits plants⁻¹ (21.19) was observed in the control T₀.

The minimum number of days to the last fruit picking (82.93) was recorded in treatment T₂ (GA₃ at 100 ppm). The maximum number of days to last fruit picking (101.07) was found in the control T₀. The maximum fruit drop per plant (1.13) was recorded for treatment T₂ (GA₃ at 100 ppm). The minimum fruit drop per plant (3.87) was observed in the control T₀. The maximum average fruit weight (119.67) (g) was recorded for treatment T₂ (GA₃ at 100 ppm). The lowest average fruit weight (81.33) (g) was found in the control T₀. The maximum fruit length (7.01) (cm) was recorded for treatment T₂ (GA₃ at 100 ppm). The minimum fruit length (4.72) (cm) was found in the control T₀. The maximum fruit width (13.50) (cm) was recorded for treatment T₂ (GA₃ at 100ppm). The

Table 3: Effect of micronutrients and PGR on yield parameters of Tomato.

Treatments	Average fruit yield plant ⁻¹ (kg)	Average fruit yield plot ⁻¹ (kg)	Average fruit yield (q ha ⁻¹)
T ₀ (Control)	2.09	25.20	470.59
T ₁ (GA ₃ @50ppm)	5.17	62.06	1158.83
T ₂ (GA ₃ @100ppm)	6.31	75.70	1413.65
T ₃ (NAA @50ppm)	4.17	50.00	933.68
T ₄ (NAA @100ppm)	4.88	58.54	1093.21
T ₅ (ZnSO ₄ @0.5%)	3.30	39.62	739.92
T ₆ (ZnSO ₄ @1%)	3.63	43.61	814.39
T ₇ (Boric acid @50ppm)	2.96	35.51	663.12
T ₈ (Boric acid @100ppm)	3.70	44.40	829.17
T ₉ (FeSO ₄ @100ppm)	2.70	32.41	605.26
T ₁₀ (FeSO ₄ @150ppm)	3.39	40.73	760.52
S.Em±	0.28	3.35	62.57
C.D. at 0.5%	0.82	9.89	184.59

minimum fruit width (8.48) (cm) was found in the control T_0 . The combination of high concentrations of micronutrients and PGRs did not always result in superior outcomes, suggesting that precise dosages and application timings are critical for achieving optimal results. This finding emphasizes the need for future research to focus on the optimal concentration range for each treatment to avoid potential toxicity or imbalances, as highlighted by Patil *et al.*, (2010) and Rahman *et al.*, (2020), Robertson, and Labate (2007).

The results for different levels of micronutrients $ZnSO_4$ (0.5, 1%), boric acid (50,100 ppm), $FeSO_4$ (100, 150 ppm), and Plant Growth Regulators GA_3 (50,100 ppm) and NAA (50,100 ppm) with the control in different treatment combinations are shown in Table 3. Statistical analysis of data on the average fruit yield plant⁻¹ (kg), average fruit yield plot⁻¹ (kg), and fruit yield (q ha⁻¹). The maximum fruit yield of plant⁻¹ (6.31 kg) was recorded for treatment T_2 (GA_3 at 100 ppm). The minimum fruit yield plant⁻¹ (2.09) (kg) was found in the control T_0 . The maximum fruit yield plot⁻¹ (75.70) (kg) was recorded in treatment T_2 (GA_3 at 100 ppm). The minimum Fruit yield plot⁻¹ (25.20) (kg) was found in the control T_0 . The maximum fruit yield (1413.65) (q ha⁻¹) was recorded for treatment T_2 (GA_3 at 100 ppm). The lowest fruit yield (470.59) (q ha⁻¹) was found in the control T_0 . Our results showed that GA_3 -treated tomato plants exhibited earlier flowering, increased flower number, and better fruit set, which led to a noticeable increase in the overall yield. This finding is consistent with those of Navale *et al.*, (2010), who reported that GA_3 application increased fruit size and yield in tomatoes by promoting more favourable reproductive development. Similarly, Serrani *et al.*, (2007) found that GA application accelerated the transition from vegetative to reproductive growth, thereby enhancing flower production and improving fruit yield.

Conclusion

The present investigation on Effect of Micronutrients and PGR on the Growth, Flowering, Fruiting and Yield of Tomato found that the effect of GA_3 plant growth regulator at two different concentrations significantly increased the vegetative growth, flowering, fruiting, and fruit yield parameters of tomato, it can be concluded that T_2 (GA_3 @100ppm) had the highest influence on tomato vegetative growth, flowering, yield, and fruit quality characteristics on tomato variety Arka Samrat because GA_3 enhance the activity of apical region, leading to stem elongation and expansion of young leaves. It also stimulates apical dominance, ensuring a well-structured plant with an optimal resource allocation for growth. In terms of reproductive development, the apical point is

where floral induction begins, and GA_f at 100 ppm promotes early flowering by activating hormonal pathways that break dormancy and initiate floral primordia. This focused enhancement of apical growth ensures better plant vigour and early reproductive transition and ultimately improves fruit yield and quality.

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