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Response of Foliar Sprays of Plant Growth Regulators and Micronutrients and Their Combinations on Morphological, Flowering and Yield Attributing Traits of Tomato at North - Bihar Condition

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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

Tomato is a very important vegetable all over the world due to its nutrients enrichment and have considered as "poor man's orange" worldwide. However, the crop is threatened with low yield and sub-standard quality fruits due to various biotic and abiotic, adverse climatic and poor nutrients status of soil. In the present study, an attempt was made to test the effects of foliar sprays of naphthalic acetic acid (NAA), gibberellic acid (GA_3), zinc (Zn) and boron (B) on growth, yield and quality attributes of tomato var. Kashi Vishesh. Significant differences recorded in plant morphological parameters such as plant height, number of branches per plant, and number of leaves per plant including the number of branches at first fruit set and days to 50% flowering and yield attributing characteristics like average fruit weight (gm), equatorial diameter of the fruit (cm), polar diameter of the fruit (cm), fruit yield per plant (kg), fruit yield (t/ha) of tomato plants. The foliar spray of GA_3 50ppm + $ZnSO_4$ 0.5% resulted in the highest plant height (82.11 cm and 124.23 cm), greatest number of branches per plant (10 and 13.4) and highest number of leaves per plant (160.1 and 199.1) at 60 and 75 DAT. In terms of yield attributes, it was demonstrated the maximum average fruit weight (65.02 g), equatorial diameter (5.23 cm), polar diameter (4.92 cm), fruit yield per plant (1.53 kg) and yield per hectare (29.31 tons). Conversely, foliar spray of GA_3 at 50 ppm + Micro. mix. at 0.5% had shown nearby results of morphological and yield data. A rigorous statistical. Analysis using ANOVA was conducted and is comprehensively presented. These findings have the potential to contribute to the enhancement of tomato production in the specific Indo-Gangetic plains of North Bihar.

Keywords: Tomato; plant growth regulators; micronutrients; GA_3 and NAA; zinc and boron.

1. INTRODUCTION

The tomato, scientifically known as *Solanum lycopersicum* L. (2n = 2x= 24), is one of more than 3,000 species in the broad and diverse family Solanaceae, also referred to as Nightshade family **(**Knapp, 2002). Tomato is very nutritive vegetable for human being because of its minerals, beta-carotene, vitamins and antioxidants, all of which support excellent health. Because of its high vitamin and acid content (maleic acid, citric acid), it is often referred to as "the poor man's orange" (Jakhar et al, 2018). It can be eaten uncooked, cooked or processed into puree, ketchup, sauce, etc. ripe tomatoes are a strong source of Vitamins A and B as well as an excellent source of Vitamin C; despite having 94% water by weight, they also have high nutritional value. It tastes good, is highly enticing and relieves constipation. In recent years, tomato has gained recognition as a significant source of lycopene, a potent antioxidant that also functions as an anticarcinogenic. The medium-ripened tomato fruit, which weighs around 145 g, contains up to 40% of the daily necessary amount of 20% of Vitamin A and Vitamin C. The tomato also provides potassium, iron and calcium to the diet. Thus, it can aid in reducing vitamin and mineral deficits in many underdeveloped nations. The most significant crop in the nation is the tomato, which is planted across the nation. Its many varieties adapt to a wide range of soil types and weather circumstances. The tomato seeds, contains 24% oil which is recovered from the pulp and leftovers in the canning business. It is used in making of salad oil and production of margarine. Raw or cooked, tomato is used in various types of recipes, salads, sauces and beverages. Even though tomatoes are basically berries, which is used as a vegetable component or biproduct. Patients with constipation might benefit from tomato soup, which also makes a great appetizer. Lycopene levels in tomato fruit grow by 500 times as also increase during ripening (Bai & Lindhot, 2007).

In India, tomato holds the third rank in the vegetables next to the potatoes, onion. In our country mainly India is the second largest producer of tomato in the world after China with production 20.62 million tons in an area of 0.864 million hectare and productivity of 23.87 MT/hectare. Major Tomato growing states of India include Madhya Pradesh, Andhra Pradesh, Karnataka, Gujarat, Odisha, West Bengal, Telangana, Chhattisgarh, Maharashtra, and Bihar. Bihar ranked 10th in total production in tomato with the total production 1.12 million tons from 0.05-million-hectare area and productivity is 21.13 MT/Hectare (2022-23).

The tomato has been grown throughout every climatic zone, whereas it is susceptible to warm, humid, and cold circumstances, so as temperatures rise, viral infections develop, flower & fruit drops increase, and fruit size and quality decline (Pramanik et al, 2018). Low tomato output is typically caused by several constraints, including inadequate soil fertility, water scarcity, poor agricultural skills, disease & insect attack, a lack of input access, and a hostile climate (Bargel et al, 2005). Failure to modify cultivars and poor fruit growth of existing varieties, particularly in hot weather when tomato demand is exceptionally high, is among the issues growers experience in tomato production, having available land to produce. The challenge of disrupted tomato flower and fruit setting, caused by elevated temperatures and humidity, significantly diminishes yield due to poor pollination and fertilization. Developing heat-tolerant tomato varieties proved challenging due to factors like moderate inheritance levels and lower-yielding cultivars (Alam and Khan, 2002). In response, the application of plant growth regulators and micronutrients has gained prominence as a strategy to enhance plant and fruit growth, fruit size and overall yield in horticultural crops. Environmental conditions, particularly temperature variations, critically influence tomato fruit setting, impacting factors like pollen production and dehiscence (Choudhury et al, 2013). The major limiting variables in maintaining and growing tomato yield are rising temperatures, viral diseases, and salinity, most of the micronutrients are deficient in calcareous soil of North Bihar. Salicylic acid/ NAA and gibberellins and micronutrients and their combination can play very important role to regulate flowering and fruit development under limiting environmental conditions. Scientists and farmers believe that using growth regulators to combat various biotic and abiotic challenges in tomato agriculture is the best option.

2. MATERIALS AND METHODS

2.1 Site, Design and Plant Material of Experiment Trial

The experimental trial was carried out during the actual time frame, likely from September 2021 to February 2022 at the Vegetable Research Farm of Dr Rajendra Prasad Central Agricultural University, located in Pusa (Samastipur), Bihar. Geographically, this research farm is positioned at a latitude of 25.980 N and a longitude of 85.680 E, with an elevation of 52.0 meters above mean sea level (MSL). The material being studied solely consisted of one genotype, and the variety utilised was "Kashi Vishesh." This variety was created using a donor parent, *L.hirsutum f. spp. glabaratum* B6013, in a pedigree backcross selection process. The plants were high-producing determinate types, dark green, with red fruits that are spherical in shape and vary in size from medium to large in weight. TLCV (Tomato Leaf Curl Virus) resistant. The seeds were purchased at the ICAR-IIVR in Varanasi.

The research trial adopted a randomized block design (RBD) with three replications. The experiment took place at RPCAU Vegetable Research Farm in Pusa, Samastipur. The experimental materials were subsequently transplanted on 23 October 2021, in a gross area of 310.625 m^2.

2.2 Treatments of Investigation

Details of the treatments were T_1(Borax 0.2%), T_2($ZnSO_4$ 0.5%), T_3(Micro. Mix. 0.5%), T_4(NAA 50ppm), T_5(NAA 50 ppm + Borax 0.2%), T_6 (NAA 50 ppm+$ZnSO_4$ 0.5%), T_7(NAA 50 ppm + Micro. Mix. 0.5%), T_8(GA_3 50 ppm), T_9(GA_3 50 ppm + Borax 0.2%), T_{10}(GA_3 50 ppm + $ZnSO_4$ 0.5%), T_{11} (GA_3 50 ppm + Micro. mix. 0.5%), T_{12} (Control).

2.3 Morphological Parameters

Observation of morphological parameters such as plant height, number of branches per plant and number of leaves per plant including the number of branches at first fruit set and days to 50% flowering. During the morphological observation a total of five plants were, randomly selected from each plot and the height (cm), number of branches and compound leaves per plant no. of branches at 1st fruit set of each plant and days to 50% flowering was measured at 45, 60 and 75 DAT and then mean of all value were calculated.

2.4 Yield and Yield Attributing Traits

Yield attributing characteristics like average fruit weight (g), equatorial diameter of the fruit (cm), polar diameter of the fruit (cm), fruit yield per plant (kg), fruit yield (t/ha) of tomato plants were recorded after harvesting and then mean of all values were calculated.

3. RESULTS AND DISCUUSION

3.1 Morphological Parameters

The results of different concentrations of plant growth regulators and micronutrients in different treatments combination presented in Table 1. It was observed that statical analysis of data of plant height (cm), number of branches and leaves per plant, branch at 1st fruit set and days to 50% flowering of tomato shows significant which measured at 45, 60, and 75 DAT and then mean of all values were calculated. At this initial stage i.e., at 45 days after-transplanting, the plant height remained relatively consistent regardless of growth regulators and micronutrients. Maximum numerical value (56.4 cm) was recorded with T_{11} (GA_3 at 50 ppm + Micro. mix. at 0.5%) and minimum (38.7 cm) with T_{12} (control). However, notable disparities in plant height were observed at the 60 and 75 days after-transplanting the reason behind it growth regulators and micronutrients.

Maximum plant height was recorded with Treatment T_{10}, involving the application of GA_3 at 50 ppm along with $ZnSO_4$ at 0.5%, resulted in the tallest plants height (82.11 cm and 124.23 cm) which was recorded statically at par with Treatment T_{11} (GA_3 at 50 ppm + Micro. mix. at 0.5%) with plant height 80.62 cm and 115.57 cm whereas minimum plant height (60.3 cm and 95.6 cm) was recorded with T_{12} (control) at the 60 and 75 days after transplantation respectively.

Notably, maximum number of branches per plant was recorded with Treatment T_{10}, involving the application of GA_3 at 50 ppm along with $ZnSO_4$ at 0.5%, resulted in the number of branches per plants (10 and 13.4) which was recorded statically at par with Treatment T_{11} (GA_3 at 50 ppm + Micro. mix. at 0.5%) with number of branches per plant 9.6 and 12.5 whereas minimum number of branches per plant (6.3 and 9.3) was recorded with T_{12} (untreated control) at the 60 and 75-days after transplantation respectively.

Table 2 clearly indicate that maximum number of leaves per plant was recorded with Treatment T_{10}, involving the application of GA_3 at 50 ppm along with $ZnSO_4$ at 0.5%, resulted in the number of leaves per plants (160.1 and 199.1) which was recorded statically at par with Treatment T_{11} (GA_3 at 50 ppm + Micro. mix. at 0.5%) with number of leaves per plant 146.8 and 193.9 whereas minimum number of leaves per plant (119.7 and 157.6) was recorded with T_{12} (untreated control) at the 60 and 75-days after transplanting respectively.

This could be because substances like gibberellin induce cell division, cell elongation, cell enlargement and it also works as a stimulator on shoot and root development, which may have balanced for increasing nutrient absorption and translocation and zinc activates the numbers of enzymes like dehydrogenase, aldolases, isomerases which are ultimately leads to better growth of plants. Shah (2004), Pramanik et al. (2017), Shittu and Adeleke (1999) and Sanyal et al. (1995) showed similar results in their experiment.

Flowering and Fruiting Characters: Effect on florigenic properties may be due to gibberellic acid and zinc which facilitate the synthesis and transmission of auxin alongside other signalling molecules. Moreover, they play a pivotal role in alleviating the dormancy of flower buds. The flowering-promoting attributes of GA_3, evident in its ability to induce flowering across diverse plant species. Notably, GA_3 has been shown to enhance floral primordia in tomatoes leading to a higher number of blossoms per plant by stimulating flower and branch proliferation. In the context of tomato, GA_3 has exhibited a propensity for increasing the average flower per plant through its positive influence on branch and flower cluster numbers. These results are supported with findings in various vegetables such as snap beans, okra, and tomatoes, as recorded by Kumar et al. (2014), Megbo (2010), Uddain et al*.,* (2009), Choudhury et al*.,* (2013). Das et al*.*, (2015).

3.2 Yield Attributing Traits

Notably, maximum number of average weights of the fruit was recorded with treatment T_{10}, involving the application of GA_3 at 50 ppm along with $ZnSO_4$ at 0.5%, resulted in average fruit weight (65.02 g) which was recorded statically at par with Treatment T_{11} (GA_3 at 50 ppm + Micro. mix. at 0.5%) with average fruit weight (63.34 g) whereas minimum average fruit weight (39.85 g) was recorded with T_{12} (control).

Notably, maximum equatorial diameter of the fruit was recorded with Treatment T_{10}, (GA_3 at 50 ppm along with $ZnSO_4$ at 0.5%), resulted in equatorial diameter (5.23 cm) which was recorded statically at par with Treatment T_{11} (GA_3 at 50 ppm + Micro. mix. at 0.5%) with range of (5.0 cm) whereas minimum equatorial diameter of fruit (3.67 cm) was recorded with T_{12} (control).

Table 1. Influence of PGR's and Micronutrients on morphological characters of tomato

Treatments	Plant Height(cm)			Number of branches per plant		
	45 DAT	**60 DAT**	**75 DAT**	**45 DAT**	**60 DAT**	**75 DAT**
T_1(Borax 0.2%)	40.7	63.3	98.6	3.9	7.5	11.7
T_2($ZnSO_4$ 0.5%)	42.7	66.2	104.7	3.8	7.7	11.5
T_3(Micro. Mix. 0.5%)	41.7	65.3	102.1	3.7	7.6	11.5
T_4(NAA 50 ppm)	41.6	64.5	105.6	3.7	7.7	11.6
T_5(NAA 50 ppm + Borax 0.2%)	46.4	68.7	105.1	3.7	7.5	12.01
T_6 (NAA 50 ppm+$ZnSO_4$ 0.5%)	49.7	71.1	102.9	3.8	8	11.7
T_7(NAA 50 ppm + Micro. Mix. 0.5%)	44.2	64.1	107.6	3.8	8.1	12.1
T_8(GA_3 50 ppm)	47.3	69.5	104.3	4.01	8.1	12.03
T_9(GA_3 50 ppm + Borax 0.2%)	51.1	71.3	105.5	4.03	8.3	12.05
T_{10}(GA_3 50 ppm + $ZnSO_4$ 0.5%)	56.1	82.1	121.2	4.5	10	13.4
T_{11}(GA_3 50 ppm + Micro. mix. 0.5%)	56.4	80.6	115	4.6	9.6	12.5
T_{12}(Control)	38.7	60.3	95.6	2.7	6.3	9.3
SE±m	2.2	3.4	4.1	0.2	0.3	0.4
C.D. (P=0.05%)	NS	10.1	11.9	NS	0.9	1.2

**SE±m= Standard error of the mean, C.D. = Critical Difference.*

Table 2. Influence of PGR's and Micronutrients on flowering and fruiting characters

Treatments	Numbers of leaves per plant			Days to 50% flowering	Numbers of branches at 1st Fruit Set
	45 DAT	60 DAT	75 DAT		
T_1(Borax 0.2%)	62.1	124.5	165.6	52.21	8.33
T_2($ZnSO_4$ 0.5%)	62.2	129.5	162.8	48.66	9.14
T_3(Micro. Mix. 0.5%)	61.9	128.5	166.4	49.93	8.34
T_4(NAA 50 ppm)	62.1	127.4	166.4	50.17	8.33
T_5(NAA 50 ppm + Borax 0.2%)	64.5	135	171.6	51.73	9.33
T_6(NAA 50 ppm+$ZnSO_4$ 0.5%)	65.7	137.8	173.3	50.39	8.01
T_7(NAA 50 ppm + Micro. Mix. 0.5%)	62.9	130.7	170.3	51.12	8.33
T_8(GA_3 50 ppm)	65.1	136.3	172.3	51.25	8.03
T_9(GA_3 50 ppm + Borax 0.2%)	66.3	139.2	174.6	49.81	8.21
T_{10}(GA_3 50 ppm + $ZnSO_4$ 0.5%)	76.8	160.1	199.1	43.56	7.67
T_{11}(GA_3 50 ppm + Micro. mix. 0.5%)	76.9	146.8	193.9	43.33	7.10
T_{12}(Control)	60.6	119.7	157.6	54.28	9.67
SE±m	3.1	5.7	6.7	2.24	0.38
C.D. (P=0.05%)	9.1	16.8	19.7	6.58	1.10

**SE±m= Standard error of the mean, C.D. = Critical Difference.*

Table 3. Influence of PGR's and Micronutrients on yield attributing characters of tomato

Treatments	Average weight of the fruit	Equatorial diameter of fruit(cm)	Polar diameter of the fruit (cm)	Average yield per plant	Yield per hectare (t/ha)
T_1(Borax 0.2%)	42.3	4.19	4.07	1.16	17.69
T_2($ZnSO_4$ 0.5%)	47.22	4.01	4.10	1.11	19.56
T_3(Micro. Mix. 0.5%)	45.64	4.12	4.17	1.05	21.23
T_4(NAA 50 ppm)	50.49	4.39	4.27	1.14	22.28
T_5(NAA 50 ppm + Borax 0.2%)	55.33	4.58	4.38	1.22	23.61
T_6 (NAA 50 ppm+$ZnSO_4$ 0.5%)	55.57	4.50	4.29	1.26	24.28
T_7(NAA 50 ppm + Micro. Mix. 0.5%)	50.22	4.44	4.36	1.18	23.65
T_8(GA_3 50 ppm)	53.63	4.52	4.37	1.25	24.75
T_9(GA_3 50 ppm + Borax 0.2%)	57.13	4.61	4.38	1.29	25.53
T_{10}(GA_3 50 ppm + $ZnSO_4$ 0.5%)	65.02	5.23	4.92	1.53	29.31
T_{11}(GA_3 50ppm + Micro. mix. 0.5%)	63.34	5.00	4.68	1.40	27.35
T_{12}(Control)	39.85	3.67	3.54	0.82	5.99
SE±m	2.08	0.18	0.17	0.06	1.08
C.D. (P=0.05%)	6.11	0.52	0.50	0.17	3.16

**SE±m= Standard error of the mean, C.D. = Critical Difference*

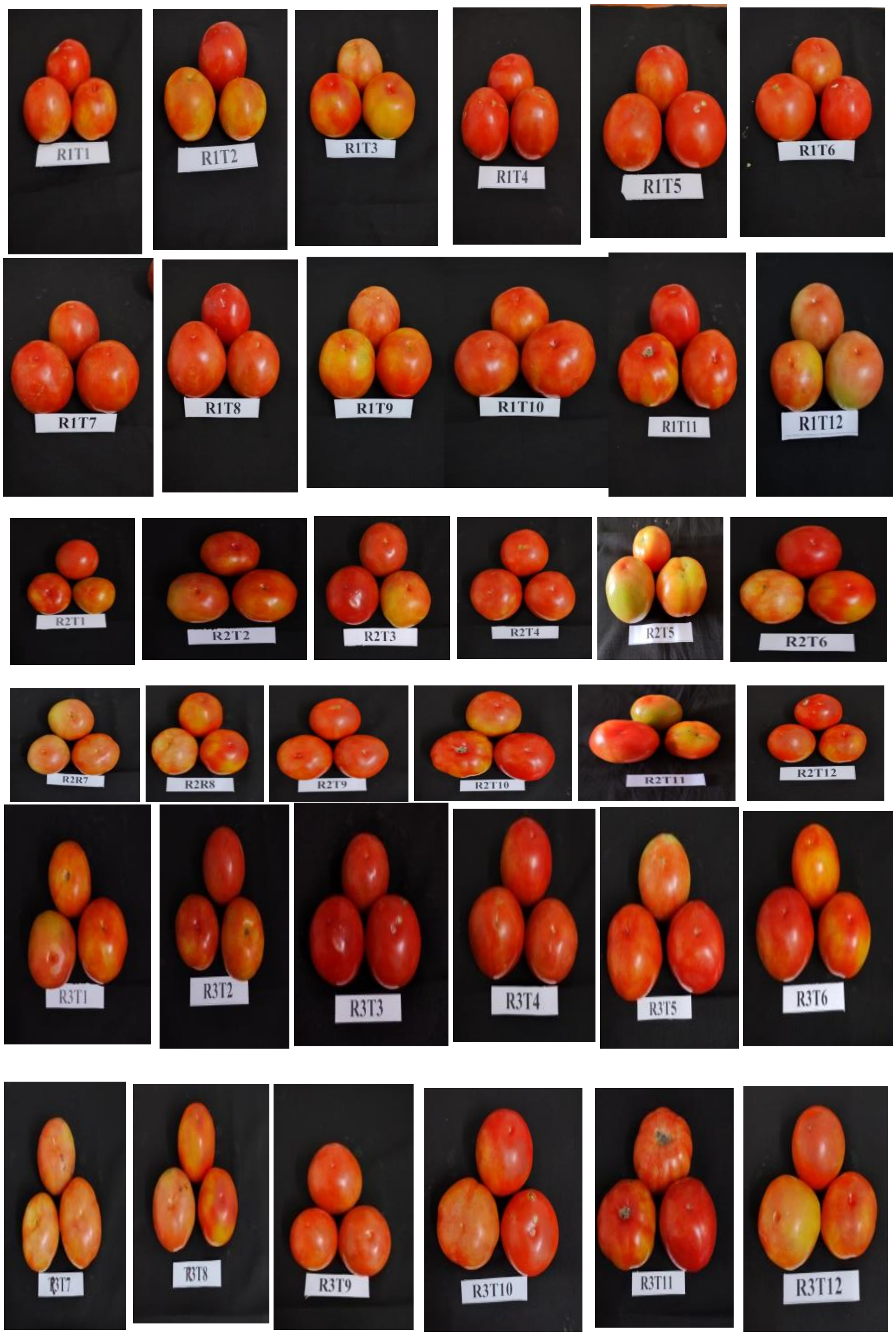

Fig. 1. Tomato samples of twelve treatments of each replication

Notably, maximum polar diameter of the fruit in cm was recorded with Treatment T_{10}, (GA_3 at 50 ppm along with $ZnSO_4$ at 0.5%), resulted in polar diameter (4.92 cm) which was recorded statically at par with Treatment T_{11} (GA_3 at 50 ppm + Micro. mix. at 0.5%) with range of (4.68 cm) whereas minimum polar diameter of fruit (3.54 cm) was recorded with T_{12} (control).

Notably, maximum fruit yield per plant was recorded with Treatment T_{10}, (GA_3 at 50 ppm along with $ZnSO_4$ at 0.5%), resulted in fruit yield per plant (1.53 kg) which was recorded statically at par with Treatment T_{11} (GA_3 at 50 ppm + Micro. mix. at 0.5%) with range of (1.40 kg) whereas minimum fruit yield per plant (0.82 kg) was recorded with T_{12} (control).

Substantial impact noticed from varying levels of PGRs (Plant Growth Regulators) and micronutrients on the average yield per hectare. Notably, maximum yield per hectare was recorded with Treatment T_{10}, involving the application of GA_3 at 50 ppm along with $ZnSO_4$ at 0.5%, resulted in yield per hectare (29.31 ton) which was recorded statically at par with Treatment T_{11} (GA_3 at 50 ppm + Micro. Mix. at 0.5%) with range of (27.35 ton) whereas minimum fruit yield per plant (15.99 ton) was recorded with T_{12} (control).

Remarkably, the application of GA_3 at 50 ppm combined with $ZnSO_4$ at 0.5% yielded the most substantial effects on yield attributes and yield per hectare. This combination exhibited superior outcomes, manifesting higher values across yield parameters. The subsequent ranks were occupied by GA_3 at 50 ppm + Micro. Mix at 0.5% and GA_3 at 50 ppm + Borax at 0.2%. Conversely, the control, yielded comparatively lower results in this context.

This could be due to Zn plays important role on growth and development as well as carbohydrates, protein metabolism and sexual fertilization of plants. Zinc stimulates a variety of enzymes that aid in retaining of fruits and flowers and seed formation at the later phases of crop growth. Plant growth regulators play a pivotal role in potentially augmenting fruit length. These regulators facilitate processes that induce semi-permeable membrane loosening, thereby engendering a heightened degree of cellular flexibility crucial for role in increased fruit size of tomato. Growth regulators like NAA and GA_3 on pivotal physiological processes (Saha B. et al., 2023). These include bolstering the photosynthetic rate and facilitating cell development, which in turn promotes the efficient translocation of photosynthates. Such actions collectively enhance fruit quantity, size, and quality. GA_3 reaffirms its pivotal role in advancing fruit growth and development. This includes inhibiting fruit senescence and actively participating in the initiation of floral and reproductive organ formation. The analogous function of Gibberellic acid in driving fruit size and quality through cell elongation and developmental influence is underscored. These results are supported with findings of Mondal S. el al., (2023), Pramanik et al., (2018), Baby et al., (2018), Swetha et al., (2018), Prasad and Kumar (2003), Mukati et al., (2019), Rahman et al. (2015), Arora et al., (2016), Singh et al. (2018), Bisht et al. (2018) Yadav, (2018), Ujjwal et al. (2018), Jakhar et al. (2018), Tomar et al. (2017), Akand et al. (2015), Sarkar et al. (2014).

4. CONCLUSION

Upon thorough examination of the experiment's outcomes, a consistent trend emerged, culminating in the study concludes that applying plant growth regulators and micronutrients yielded significantly superior results across various growth parameters. Notably, Treatment T_{10} (GA_3 at 50 ppm + $ZnSO_4$ at 0.5%) demonstrated the most superiority, followed by Treatment T_{11} (GA_3 at 50 ppm + Micro. mix. 0.5%), when compared to the control group T_{12} (distilled water only) resulting in higher plant growth and ultimately boosting tomato yield within the context of North Bihar conditions**.** This study can be extended to screen other tomato varieties and their growth and yield in different parts of the country in terms of enhance production and productivity of tomato.

5. FUTURE ASPECTS

In North Bihar, future tomato production will benefit from zinc and boron supplementation to address nutrient deficiency, improving yield and tomato quality. Plant growth regulators will enhance growth, fruit set and stress tolerance in tomato. Integrated approaches, leveraging new technology and sustainable practices, will optimize productivity and resilience in changing climate**.**

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 no competing interests exist.

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