Plant Archives Vol. 25, No. 1, 2025 pp. 2275-2281 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.1.329

EFFECT OF PGR AND ZINC ON GROWTH, YIELD AND QUALITY OF TOMATO (*SOLANUM LYCOPERSICUM* L.)

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(Date of Receiving-07-02-2025; Date of Acceptance-12-04-2025)

ABSTRACT

The experiment comprised of nine treatments, which were replicated three times and laid out in randomized block design. The observations flowering, fruit yield and quality of tomato were recorded during study. Among all the treatment T_3: GA_3 80ppm was found superior in relation to plant growth, quality and fruit yield of tomato. The maximum plant height (46.44, 78.68 and 105.84 cm) and number of branches per plant (4.33, 7.66 and 12.99) at 30, 60 and 90 DAT was recorded in treatment T_3: GA_3 80ppm. Whereas, the minimum plant height (36.42, 57.66 and 94.46 cm) was found in (T_0) control. Hence, from the present investigation it may be concluded that the T_3: GA_3 80ppm proved the best influencing the vegetative growth, flowering, yield and fruit quality parameters of tomato cv. Varsha.

Key words : Tomato, GA_3, NAA, Zn, $ZnSO_4$.

Introduction

Tomato (*Solanum lycopersicum* L.) is an important vegetable of solanaceae family universally known as “Protective Food” having chromosome number 2n=24. It has originated from wild in the Peru-Equador-Bolivia region of the Andes, South America (Rick, 1969) and grown in almost every corner of the world (Roberston and Labate, 2007). It is a versatile vegetable for culinary purpose and generally consumed as Salad, Soup, Ketchup, Sauce, Chutney, pickles, powder paste, juice, puree and whole canned fruits. The unripe green fruits are used for making pickles and preserves and are consumed after cooking as vegetable (Kaur *et al*., 2004; Arya, 2004). Tomatoes have been linked with reduced risk of some neurological diseases and have anti-cancer benefit. The leading tomato producing countries of the world are China, India, Nigeria Pakistan, Turkey, Egypt, United States, Italy, Mexico, Cameroon, Russian Federation and Iran. The total area under tomato cultivation is 51.67 million hectare with production of 189.13 million tons (FAO, 2021). In India, at present the total area under tomato cultivation is 0.85 million hectares and production is 20.82 million tones. Top ten state for tomato production in India are; Madhya Pradesh, Karnataka, Andhra Pradesh, Tamil Nadu, Odisha, Gujarat, West Bengal, Chhattisgarh and Maharashtra and Bihar (Anon, 2024).

Use of plant growth regulators improved the production of tomato and other vegetables, inspite of better growth and yield (Saha, 2009). Gibberellin promotes shoot growth by accelerating the cell elongation and cell division in the sub apical meristmetic region which increases the length of internodes. Gibberellin regulates the mitotic activity of the sub apical meristem. Physiological effect of gibberellins is elongation of stem, by increasing the length of internodes, parthenocarpic fruit formation, increase in the size of leaves and fruits and also enhances cell division and cell size. GA_3 increases the leaf size, stem length and fruit set (Serrani *et al*., 2007). The application of Auxin and Gibberellins are effective in increasing quality of tomato (Pramanik *et al*., 2018). While, reduction in fruit dry mater and weight per fruit due to application of 40ppm NAA and 10ppm GA_3 as compared to 20ppm NAA and 5ppm GA_3 was observed in tomato (Singh and Lal, 2002). The effect of NAA has

been observed mainly in cell elongation, improving phototropism, apical formation, respiration and flower bud initiation. The mode of action of NAA direct in synthesis of cell wall components, permeability through plasma membrane, function as coenzyme or co enzyme components, induction of synthesis of specific RNA and protein which in turn leads to an increase in cell wall elasticity and extension (Krishnamur, 1981). In fact, the use of growth regulators had not only increased the production of tomato other vegetables but also improves the quality which ultimately led to generate interest between the scientists and farmers for commercial application of growth regulators (Verma *et al.*, 2014). Combined application of 20ppm NAA and 20ppm GA_3 increases flower per cluster, number of fruits and yield as compared to the plants treated with NAA and GA_3 alone (Hossain *et al.*, 2018). Application of different dose of Zn significantly increased plant growth and yield of tomato (Gopal and Sarangthem, 2018). Both zinc and GA_3 significantly influenced all observed parameters, with the best treatment being Z_1G_2 (Z_1 @ 0.5 kg ha^{-1} + G_2 @ 75ppm) for yield and quality of tomato (Rahman *et al.*, 2019). Considerable research work has been done on the aspect of foliar application of micronutrients in different crops and the experimental results indicated not only an increase in yield up to 20 percent but also helpful way to sustain crop production Arora *et al.* (1982) reported that micronutrients like boron, copper, molybdenum and zinc through foliage application can improve the vegetative growth, fruit set and yield of tomato. In this paper, we tried to find out the optimum, concentration of PGR and Zn for increasing growth and yield.

Materials and Methods

The present experiment was laid out in the field of Horticulture Research Farm, Department of Horticulture, Chandra Bhanu Gupta Agriculture P.G. College, Bakshi Ka Talab, Lucknow during *Kharif* season of Crop 2023-24. Lucknow is situated at an altitude of 123 meter above mean sea level at 26°84' N latitude and 80°94' E longitude. The climate of the Lucknow is sub-tropical with hot, dry summers and cool winters. Hot desiccating winds (Loo) are regular feature during summers, whereas there may be occasional spell of frost during the winters. The average rainfall in this area is approximately 100-120 cm, with maximum concentration during the monsoon i.e., July to October, with a few occasional showers during the rainy months.

The experiment was laid out in Randomized Block Design, comprising of nine treatments (Control, GA_3 20, 40, 80ppm, NAA 20, 40, 80ppm, $ZnSO_4$ 250, 500ppm) and three replications for each treatment, making nine treatment combinations. Treatments were randomly arranged in three replications. Subsequent observations were recorded at 30, 60, 90 days after transplanting. The data based on the mean of individual plants selected for observation were statistically analyzed to find out overall total variability present in the material under study for each character.

Results

Growth parameters

Effect of PGR and Zinc on plant height (cm) of tomato

The data regarding plant height as influenced significantly by PGR and Zinc application at 30, 60 and 90 DAT are given in Fig. 1. The plant height increased with advancement of age of the plant up to 90 DAT under all the treatments. Maximum plant height at all the stages of growth (46.44, 78.68 and 105.84 cm, respectively) was recorded with treatment T_3: GA_3 80ppm. While, minimum (36.42, 57.66 and 94.46 cm at 30, 60 and 90 DAT, respectively) plant height was registered under the treatment of T_0 (control). The plant height increased significantly with each increase in GA_3, NAA and Zinc levels at all the stages of plant growth except at initial stage. At 30 DAT, plant height with treatment T_3 was at par with T_6: NAA 80ppm (45.88 cm) and it was on par with treatment T_2 (45.62 cm) and T_5 (45.14 cm).

Effect of PGR and Zinc on number of branches plant^{-1} in tomato

The data pertaining to number of branches $plant^{-1}$ as influenced significantly by PGR and Zinc at 30, 60 and 90 DAT presented in Fig. 2. Maximum number of branches $plant^{-1}$ (4.33, 7.66 and 12.99, respectively) was recorded with treatment T_3: GA_3 80ppm. Whereas, the minimum number of branches $plant^{-1}$ was recorded under T_0 (control) which were 2.33, 3.99 and 8.33 on the observation at 30, 60 and 90 DAT, respectively. The number of branches $plant^{-1}$ was ranged from 2.99 to 4.33, 2.66 to 3.88 and 2.44 to 2.99 when treated with GA_3, NAA and Zinc, respectively. Thus, it was quite clear that PGR application at different levels proved their efficacy over zinc levels and control. However, all the treatments produced significations higher number of branches as compared to control.

Effect of PGR and Zinc on days of first fruit picking of tomato

The data regarding the days of first fruit picking was presented under different treatments in Table 01. Treatment T_3: GA_3 80ppm showed earliness (60.33 days)

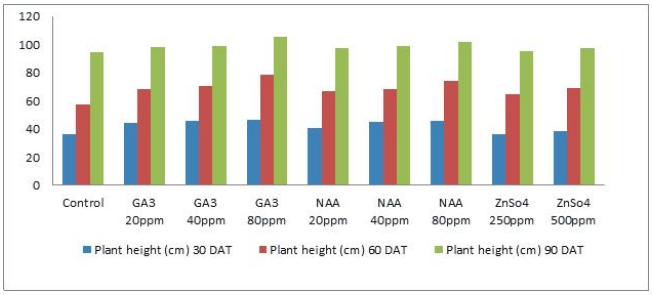

Fig. 1 : Effect of PGR and Zinc on plant height (cm) of tomato at different stages of plant growth.

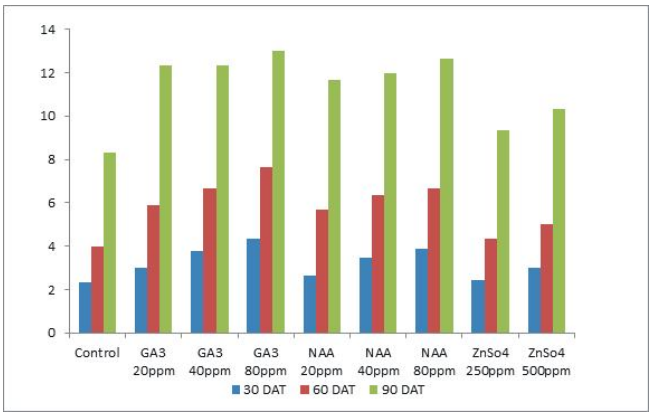

Fig. 2 : Effect of PGR and Zinc on days taken to first fruit set of tomato.

in first fruit picking. While, late (72.33 days) in first fruit picking was observed under treatment T_0 (control). Thus, data revealed that higher concentrations of chemical exhibited earliness in first fruit picking over lesser concentration of the treatments.

Yield and yield attributes

Effect of PGR and Zinc on number of fruit plant^{-1} of tomato

The data with respect to number of fruit plant^{-1} as influenced significantly by different treatments are given in Table 2. Maximum number (32.00) of fruit plant^{-1} was recorded with treatment T_3: GA_3 80ppm. Whereas, the minimum number (13.66) of fruit plant^{-1} was under T_0 (control). GA_3 treated plant gave highest number of fruits per plant over rest of the treatments. It was quite clear that increase in levels of PGR increased the number of fruits plant^{-1}. An increase in number of fruit plant^{-1} was also found with zinc application (T_8) but it was on par with (T_7).

Effect of PGR and Zinc on average fruit weight (g) of tomato

The result of different levels of PGR and Zinc differed significantly the fruit weight in tomato was shown in Table 2. It was observed that statistical analysis of data on average fruit weight (g) of tomato shows significant. The maximum average fruit weight (59.33 g) was recorded

Table 1 : Effect of PGR and Zinc on days taken to first fruit set and days of first fruit picking of tomato.

Notations	Treatments	Days taken to first fruit set	Days of first fruit picking
T_0	Control	68.66	72.33
T_1	GA_3 20ppm	55.33	62.33
T_2	GA_3 40ppm	54.66	61.66
T_3	GA_3 80ppm	54.00	60.33
T_4	NAA 20ppm	56.00	64.66
T_5	NAA 40ppm	55.66	63.66
T_6	NAA 80ppm	55.00	63.33
T_7	$ZnSo_4$ 250ppm	56.33	65.66
T_8	$ZnSo_4$ 500ppm	57.33	66.33
	SE(m) ±	0.70	0.52
	C.D. at 0.5	2.12	1.57

in both treatments T_3: GA_3 80ppm and T_6: NAA 80ppm. Which were closely followed by T_5 (58.30) and T_2 (58.0). Whereas, the minimum average fruit weight (34.00 g) was found in control (T_0).

Effect of PGR and Zinc on fruit length (cm) of tomato

The result of different levels of PGR and Zinc varied the fruit length as shown in Table 2. It was observed that statistical analysis of data on fruit length (cm) of tomato shows significant. The maximum fruit length (4.65 cm) was recorded in both treatments T_3: GA_3 80ppm and T_6: NAA 80ppm closely followed by T_2: GA_3 40ppm, T_5: NAA 40ppm and T_4: NAA 20ppm. Whereas, the minimum fruit length (3.32 cm) was found in control (T_0).

Effect of PGR and Zinc on fruit width (cm) of tomato

The result of different levels PGR and Zinc improved significantly the fruit width was shown in Table 2. It was observed that statistical analysis of data on fruit width (cm) of tomato shows significant. The maximum fruit width (9.33 cm) was recorded in treatment T_3: GA_3 80ppm followed by T_1: GA_3 20ppm. Whereas the minimum fruit width (4.00 cm) was found in control (T_0).

Effect of PGR and Zinc on fruit yield plant^{-1} kg of tomato

Data with respect to fruit yield plant^{-1} influenced significantly by different levels PGR and Zinc was shown in Table 2. It was found that statistical analysis of data on fruit yield plant^{-1} of tomato revealed significant. The maximum fruit yield plant^{-1} (2.17) was recorded in treatment T_3: GA_3 80ppm followed by T_2: GA_3 40ppm. Whereas, the minimum fruit yield plant^{-1} (0.54) was observed in control (T_0).

Effect of PGR and Zinc on fruit yield (ha^{-1} t) of tomato

Table 2 : Effect of PGR and Zinc on no. of fruits per plant, Average fruit weight (g), Fruit length (cm) and Fruit width (cm) of tomato.

Notations	Treatments	No. of fruits per plant	Average fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Fruit yield (plant^{-1} kg)	Fruit yield (ha^{-1} t)
T_0	Control	13.66	34.00	3.32	4.00	0.54	12.14
T_1	GA_3 20ppm	29.33	57.33	4.00	7.66	1.37	30.66
T_2	GA_3 40ppm	30.66	58.00	4.32	8.33	1.73	38.73
T_3	GA_3 80ppm	32.00	59.33	4.65	9.33	2.17	48.33
T_4	NAA 20ppm	23.33	57.33	4.32	7.66	1.14	25.33
T_5	NAA 40ppm	24.66	58.30	4.33	8.00	1.23	27.40
T_6	NAA 80ppm	25.33	59.33	4.65	8.66	1.35	29.99
T_7	$ZnSo_4$ 250ppm	22.66	48.33	3.32	7.66	0.72	15.99
T_8	$ZnSo_4$ 500ppm	23.33	49.00	3.65	8.00	0.84	18.66
	SE(m)±	0.32	0.44	0.11	0.28	0.01	0.32
	C.D. at 0.5	0.98	1.33	0.34	0.86	0.04	0.99

Table 3 : Crop economics.

Notations	Treatments	Cost of cultivation	Gross return	Net return	B:C ratio
T_0	Control	96550	121400.00	24850.00	1:1.25
T_1	GA_3 20ppm	123079	306600.00	183521.00	1:2.48
T_2	GA_3 40ppm	138079	387333.30	249254.30	1:2.80
T_3	GA_3 80ppm	168079	483300.00	315221.00	1:2.87
T_4	NAA 20ppm	108579	253300.00	144721.00	1:2.33
T_5	NAA 40ppm	109079	273300.00	164221.00	1:2.50
T_6	NAA 80ppm	110079	299933.30	189854.30	1:2.72
T_7	$ZnSo_4$ 250ppm	108104	159933.30	51829.30	1:1.47
T_8	$ZnSo_4$ 500ppm	108129	186600.00	78471.00	1:1.72
	SE(m) ±		3286.03	3286.03	0.03
	C.D. at 0.5		9936.34	9936.34	0.09

It is evident par the data related to fruit yield as different levels PGR and Zinc in different treatments combination was shown in Table 2. It was observed that statistical analysis of data on fruit yield t ha^{-1} of tomato shows significant. The maximum fruit yield (48.33 ha^{-1} t) was recorded in treatment T_2: GA_3 80ppm. Whereas the minimum fruit yield (12.14 ha^{-1} t) was estimated in control (T_0). It is of worthy to mention that GA_3 application was formed more produce as compared to rest of the treatment.

Economic parameters

Cost of cultivations

The data showed that cost of cultivation varied mainly due to variation in cost of inputs required for different nutrient management practices. The maximum cost of cultivation (Rs 168079.00) was incurred in the treatment T_3: GA_3 80ppm closely followed by the treatment T_2: GA_3 40ppm. Whereas, among various PGR and Zinc treatment the lowest cost of cultivation (Rs 96550) was associated with control (T_0).

Gross return

The data showed that maximum Gross return (Rs. 483300.00) was obtained in treatment T_3: GA_3 80ppm. The minimum Gross return (Rs 121400.00) was registered in the treatment control (T_0).

Net return

The data indicated that among PGR and Zinc treatments maximum net return (Rs 315221.00) was recorded in the treatment having T_3: GA_3 80ppm. The minimum net return was noted in the treatment of control (T_0). Foliar application of PGR obtained higher net return because of lower cost of cultivation and higher productivity.

Benefit: cost ratio

The data regarding to Benefit: cost ratio are clear from the data that maximum Benefit: cost ratio (B: C ratio) was estimated with foliar application of PGR.

Among foliar PGR and Zinc applied treatment application of T_3: GA_3 80ppm proved to be more profitable than rest of the treatments. The minimum Benefit: cost ratio (1:1.25) was observed with control (T_0).

Discussion

Effect of PGR and Zinc on growth parameters of tomato

The observation on various growth parameters was observed at 30, 60 and 90 DAT revealed significant differences among the treatment in the years 2023 – 2024 (Fig. 1). The application of PGR and Zinc significantly increased the growth and flowering parameters *viz*., plant height (cm), number of branches plant^{-1}, days of 50% flowering, number of flower plant^{-1}, days taken to first fruit set, days of first fruit picking. The maximum plant height at all the stages of growth (46.44, 78.68 and 105.84 cm, respectively) was recorded with treatment T_3: GA_3 80ppm. Whereas, the minimum plant height was recorded under T_0: control which were 36.42, 57.66 and 94.46 cm on the observation at 30, 60 and 90 DAT, respectively. This increase in growth parameters might be due to characteristics virtue of growth regulators and micronutrients which promoted cell elongation, which has promoted the growth of all vegetative parts (Nayak *et al*., 2022).

The maximum number of branches plant^{-1} (4.33, 7.66 and 12.99, respectively) at 30, 60 and 90 DAT was recorded in treatment T_3: GA_3 80ppm followed by T_6: NAA 80ppm. Whereas, the minimum number of branches plant^{-1} (2.33, 3.99 and 8.33, respectively) was found in T_0: Control (Fig. 2). The height of the plant and number of branches plant^{-1} were increased correspondingly with each increase in concentration of GA_3 0 to 80ppm. Thus, the maximum values of these morphological characters (growth) were recorded under GA_3 80ppm. These results are in agreement with those reported by Banu *et al*. (2024), Afrin *et al*. (2024), Rabbi *et al*. (2024), Yadav *et al*. (2023), Choudhry *et al*. (2023).

The minimum days taken to first fruit set (54.00) was recorded in treatment T_3: GA_3 80ppm followed by T_2: GA_3 40ppm. Whereas the maximum days taken to first fruit set (68.66) was found in T_0: Control (Table 1). This may be due to the role of this growth stimulating hormones for enhancing pollen germination, fertilization, fruit set, cell division and elongation after pollination. The present finding also agreed to the result of Choudhry *et al*. (2023), Yadav *et al*. (2023), Madhav *et al*. (2023) and Singh *et al*. (2024). The minimum days of first fruit picking (60.33) was recorded in treatment T_3: GA_3 80ppm followed by T_2: GA_3 40ppm. Whereas the maximum days of first fruit picking (72.33) were found in T_0: Control (Table 1). The application of GA_3 on the tomato plants improved significantly the reproduction characters of tomato crop. The number of days after transplanting required for visibility of first flower, initiation of flowering, fruit setting in the plant were increased correspondingly with each increase in the concentration of GA_3 from 0ppm to 80ppm.

Effect of PGR and Zinc on yield components and yield of tomato

The maximum number of fruit plant^{-1} (32.00) was recorded in treatment T_3: GA_3 80ppm followed by T_2: GA_3 40ppm. Whereas the minimum no. of fruit plant^{-1} (13.66) was found in T_0: Control (Table 2). Application GA_3 80ppm was found to be superior for the entire yield attribute; this may be due to the role of this growth stimulating hormones for enhancing pollen germination, fertilization, fruit set, cell division and elongation after pollination. The present finding also agreed to the result of Choudhry *et al*. (2023), Yadav *et al*. (2023), Madhav *et al*. (2023) and Singh *et al*. (2024).

The maximum Average fruit weight (59.33 g) was recorded in treatment T_3: GA_3 80ppm followed by T_6: NAA 80ppm. Whereas the minimum Average fruit weight (34.00 g) was found in T_0: Control (Table 2). These results are in accordance with Choudhry *et al*. (2023), Yadav *et al*. (2023), Madhav *et al*. (2023) and Singh *et al*. (2024). Size and weight of fruit is also an important aspect as these fruit characters are useful for yield as well as consumer acceptability.

The maximum Fruit length (4.65 cm) was recorded in treatment T_3: GA_3 80ppm followed by T_4: NAA 20ppm. Whereas, the minimum Fruit length (3.32 cm) was found in T_0: Control (Table 2). This increase in fruit length may be attributed to increase in number cell as well as elongation of cells which is characteristic action of any auxins group of chemicals. It is due to the application of NAA and GA_3 which causes stimulation of fruit growth that resulted in increased fruit weight, fruit length, and fruit width. Similar results have been reported by Choudhry *et al*. (2023), Yadav *et al*. (2023), Madhav *et al*. (2023) and Banu *et al*. (2024).

The maximum Fruit width (9.33 cm) was recorded in treatment T_3: GA_3 80ppm followed by T_6: NAA 20ppm. Whereas the minimum Fruit width (4.00 cm) was found in T_0: Control (Table 2). It is due to the application of NAA and GA_3 which causes stimulation of fruit growth that resulted in increased fruit weight, fruit length, and fruit width. Similar results have been reported by Choudhry *et al*. (2023) and Yadav *et al*. (2023).

The probable reason for the improvement in fruit size, weight in proportion to the applied rate of GA_3 80ppm might be due to stimulated rate of cell division and cell enlargement, creation of sink and accumulation of surplus photosynthetic in the developing fruit translocated from leaves due to their manufacture at faster rate and more in amount under the influence of GA_3. The enhanced diversion as primary sinks during reproductive phase.

The maximum fruit yield (2.17 kg ha^{-1}) was recorded in treatment T_3: GA_3 80ppm followed by T_2: GA_3 40ppm. Whereas the minimum fruit yield (0.54 kg ha^{-1}) was found in T_0: Control. The maximum fruit yield (48.33 t ha^{-1}) was recorded in treatment T_3: GA_3 80ppm followed by T_2: GA_3 40ppm. Whereas the minimum fruit yield (12.14 t ha^{-1}) was found in T_0: Control. It might be due to exogenous application of gibberellic acid that increases in cell wall plasticity and cell elongation Madhav *et al.* (2023). The highest (0.64 t/ha) dry red chillies yield was recorded under foliar spray GA_3 @ 50ppm (T_8) followed by (0.57 t/ha) under GA_3 @ 75ppm. Similar results were also reported by earlier workers such as Shankhwar *et al.* (2017); Naga *et al.* (2022) and Hariom and Topno (2023). The yield of fruit is directly related to the yield attributes like number of fruit $plant^{-1}$, fruit weight, fruit width and fruit length in the present experiment the values of all the yield attributes mention above were increased significantly and correspondingly with each increase in concentration of GA_3 from 0 to 80ppm (Table 3). These results are in conformity with those reported by Naga *et al.* (2022) and Hariom and Topno (2023).

Effect of PGR and Zinc on Economic parameters of tomato

Cost of cultivations

The data showed that cost of cultivation varied mainly due to variation in cost of inputs required for different nutrient management practices. The maximum cost of cultivation (Rs 168079.00) was incurred in the treatment T_3: GA_3 80ppm closely followed by the treatment T_2: GA_3 40ppm. Whereas, among various PGR and Zinc treatments (Table 3) the lowest cost of cultivation (Rs 96550) was associated with control (T_0). These results are in agreement of the findings of Panday *et al.* (2022), Himanshu *et al.* (2022), Banu *et al.* (2024) in tomato.

Gross return

The data showed (Table 3) that maximum Gross return (Rs 483300.00) was obtained in treatment T_3: GA_3 80ppm. The minimum Gross return (Rs 121400.00) was registered in the treatment control (T_0). The gross return differed under each treatment due to variation in yield obtained under the treatment. These findings are in conformity of the results reported by Panday *et al.* (2022), Himanshu *et al.* (2022), Banu *et al.* (2024) in tomato.

Net return

The data indicated that among PGR and Zinc treatments maximum net return (Rs 315221.00) was recorded in the treatment having T_2: GA_3 40ppm which was closely followed by T_3: GA_3 80ppm (Table 3). The minimum net return (Rs 24850.00) was noted in the treatment of T_0 control. Foliar application of PGR obtained higher net return because of lower cost of cultivation and higher productivity. The net monetary return was analysed by the deduction of amount increased under cost of cultivation from total gross monetary return. Similar results have also been reported by Panday *et al.* (2022), Himanshu *et al.* (2022), Banu *et al.* (2024) in tomato.

Benefit: cost ratio

The data regarding to Benefit: cost ratio was significant and estimated maximum with foliar application of PGR (Table 3). Treatment @ T_3: GA_3 80ppm while, minimum with control (T_0). The maximum Benefit: cost ratio (2.87) with GA_3 80ppm may be due to higher return as compared to other treatments. These results are in the line of earlier workers Panday *et al.* (2022), Himanshu *et al.* (2022), Banu *et al.* (2024) in tomato.

Conclusion

Among all the treatment T_3: GA_3 80ppm was found superior in relation to plant growth, quality and fruit yield of tomato. Hence, from the present investigation it can be concluded that the T_3: GA_3 80ppm proved the best influencing the vegetative growth, flowering, yield, and fruit quality parameters of tomato cv. Varsha.

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