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Effect of PGRs on growth, reproductive efficiency, and quality of tomato (*Solanum lycopersicum*) in arid regions

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ABSTRACT

An experiment was conducted during *rabi*, 2021-22 at College of Agriculture, Jodhpur to assess the effect of plant growth regulators (PGRs) on the growth, flowering, and fruiting characteristics; and quality of tomato (*Solanum lycopersicum* L.) in a randomized block design with three replications comprising 10 treatments. Three levels each of GA_3, 4-CPA, and NAA along with control were used. There was maximum plant height (47.2 cm, 61.3 cm, and 80.9 cm at 45 DAT, 60 DAT, and final harvesting, respectively), number of branches (19.4/plant), leaf area (30.6 cm^2), TSS (5.41°Brix) and ascorbic acid (22.8 mg/100g) over the control with GA_3@75 ppm, whereas minimum acidity (0.46 %) was recorded with NAA@75 ppm. The significantly higher fruit length (6.7 cm), fruit diameter (7.2cm), and fruit firmness (2.6 kg/cm^2) were recorded with 4-CPA@75 ppm. The maximum number of fruit clusters (12.0/plant), number of flowers (5.4/cluster), number of fruits (3.2/cluster), number of fruits (38.1/plant), fruit setting (59.7%), fruit weight (84.3 g) and lycopene content (6.5 mg/100g) were observed with NAA@75 ppm.

Key Words: 4-Chlorophenoxy acetic acid, flowering, fruiting, gibberellic acid, naphthalene acetic acid

Tomato (Solanum lycopersicum L.), as India's second most crucial solanaceous vegetable crop, faces challenges due to the sub-optimal growth conditions associated with global warming and climate change in arid regions. These environmental stresses negatively impact plant growth, survival, and crop yield (Choudhary et al., 2023). Besides the importance of growing adapted hybrids to both biotic and abiotic stresses (Singh et al., 2021) the productivity enhancement necessitates application of plant growth regulators (PGRs) for controlling pre-harvest fruit drops and enhancing flowerbud formation and fruit ripening. Among the PGRs, gibberellic acid (GA_3) plays a vital role in controlling various critical processes including stem elongation, enhancing flower maturation, and promoting overall plant growth. The use of GA3 in tomatoes has been shown to increase fruit setting and the number of fruits per plant (Chaudhury et al., 2013), leaf area, lycopene content, the number of fruit clusters, internode elongation, and the number of branches (Masroor et al., 2006). Additionally, 4-chlorophenoxy acetic acid (4-CPA), an auxin, positively affects the quality of tomatoes by influencing sucrose metabolism and altering acid invertase activity during ripening. The application of 4-CPA a week after anthesis has been observed to increase fruit set percentage, number of fruits per plant, fruit weight, diameter, fruits per cluster, and yield per cluster, particularly under low temperatures. Furthermore, naphthalene acetic acid (NAA) also contributes to reducing pre-harvest fruit drops and enhancing fruit setting, size, and yield. Given these challenges and the potential of PGRs, an investigation was conducted to assess the effects of GA3, 4-CPA, and NAA on the growth and quality of tomatoes in the arid regions of western Rajasthan.

MATERIALS AND METHODS

The experiment was conducted during *rabi* 2021-22 at College of Agriculture, Jodhpur, situated at an altitude of 231m amsl between $26^0 15''$ to $26^0 45''$ North latitude and $73^0 00$ to $73^0 29''$ East longitude. The location falls in agroclimatic zone of the 'Arid Western Plains Zone' of Rajasthan. The climate of Jodhpur is usually arid, with dry, warm, and sunny winters and

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average annual precipitation is about 367 mm. The average daily maximum and minimum temperature fluctuated between 16.1^{0}C-40.3^{0}C and 10.9^{0}C-36.6^{0}C, respectively, with mean daily relative humidity varying from 88.1-27.1%. The soil of experimental field was sandy-loam in texture, slightly alkaline in reaction (pH 8.2), low in organic carbon (0.13%) and available N (174 kg/ha), and medium in available phosphorus (20.2 kg/ha) and high in available potassium (325 kg/ha).

The experiment comprised 10 treatments including three levels each of GA_3 (25, 50, and 75 ppm), 4-CPA (25, 50, and 75 ppm), and NAA (25, 50, and 75 ppm) along with the control (water spray). The experiment was laid out in a randomized block design with three replications. The experimental field was prepared by two cross-harrowing followed by planking. The FYM @ 25 t/ha was thoroughly incorporated into soil at the time of harrowing. A uniform dose of 120 kg P_2O_5/ha through DAP, 80kg K_2O/ha through MoP, and 60 kg N/ha through urea was applied about 3-4 cm deep at the time of transplanting. The remaining dose of N (60 kg/ha) was applied through urea in two equal splits 35 and 60 days after transplanting (DAT) through spot application.

The 30-day old seedlings of tomato (*cv. Ansal*) were transplanted on 1 December 2021 at 60 cm x 45 cm row-to-plant spacing, respectively on flat beds in plots of 3.15m × 4.20m. The field was irrigated by maintaining uniform soil moisture. Manual weeding was performed twice, and plant-protection measures were adopted as per needs.

A stock solution of 1000 ppm of GA3, 4-CPA, and NAA was prepared in distilled water. Then, working solutions of 25, 50, and 75 ppm each of GA3, 4-CPA, and NAA were prepared by diluting the sock solutions with distilled water. Three foliar sprays of PGRs were applied 30, 45, and 60 days after transplanting (DAT) thoroughly with 500 litre water/ha. Spraying was performed early in morning to avoid rapid drying of the spray solution due to transpiration.

Observations on plant height (45 DAT, 60 DAT, and at final harvesting), number of branches at final harvesting, fruit clusters/plant at final harvesting, flowers/cluster at 75 DAT, fruits/ cluster, and fruits/plant at final harvest were recorded on five randomly selected plants in each treatment. The leaf area/plant was taken after 90 DAT from five mature and active leaves by multiplying leaf length and leaf width. The per cent fruit setting was obtained by dividing total number of fruits/cluster by the number of flowers/cluster and multiplied by 100. The fruit length, fruit diameter, and fruit weight were recorded from five randomly selected fruits from each treatment. The total soluble solids were recorded using a digital refractometer, acidity was measured from pulp of tomato fruit, ascorbic acid was estimated following AOAC (2000), lycopene content through spectrophotometer and fruit firmness was determined by a digital fruit hardness tester.

The means for all data collected from the treatments were calculated and the analyses of variance for all the characters were performed by the 'F' test. The significance of difference between pairs of means was separated by critical difference (CD) at 5% levels of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The plant height 45 DAT, 60 DAT, and at final harvesting was influenced significantly under different levels of GA_3 and NAA. Further, under different levels of 4-CPA, plant height was recorded at par of the control. There was maximum plant height of 47.2 cm, 61.3 cm, and 80.9 cm at 45 DAT, 60 DAT, and at final harvesting, respectively over the control with GA_3@75 ppm, which was found at par with GA_3@50 ppm. This may be due to the effect of GA_3 on stem elongation by rapid cell multiplication in sub-apical meristem. The NAA@75 ppm being at par with NAA@50 ppm, recorded significantly maximum plant height of 40.6 cm, 53.0 cm, and 71.3 cm at 45 DAT, 60 DAT and final harvest, respectively over control. Similar results were reported by Ujjwal *et al.* (2018). This might be due to increased photosynthetic activities, better translocation, and utilization of photosynthates due to rapid cell division in apical regions and growth stimulation. However, due to the plant deformity effect, the higher levels of 4-CPA beyond 25 ppm caused a decrease in plant height. It clarifies that higher concentrations of PGRs can impair primary plant metabolisms.

The number of branches/plant at the final harvesting and leaf area/plant at 90 DAT was influenced significantly in GA_3 and NAA over the control. However, due to the plant deformity effect of

4-CPA, number of branches and leaf area/plant could not be influenced significantly over the control. The maximum number of branches (19.4) and leaf area at 90 DAT (30.6 cm^2) were observed with GA_3@75 ppm, which was at par with GA_3@50 ppm (18.9 and 29.7 cm^2, respectively). Similar results were observed by Naz *et al*. (2020). This might be due to antimitotic action, which inhibits the suppression of apical growth of central axis, finally increasing number of branches/plant. On the other hand, GA_3 might have caused an increase in protein and enzyme synthesis, which caused shoot elongation, leading to higher leaf area. Similarly, maximum number of branches (18.2) and leaf area at 90 DAT (27.2 cm^2) were observed with NAA@75 ppm, which was at par with NAA@50 ppm. It may be due to more photosynthetic activities in plants leading to increased leaf area. Similar results were observed by Naz *et al*. (2020).

The number of flowers/cluster at 75 DAT, number of fruit clusters/plant at final harvesting, number of fruits/cluster, number of fruits/plant at final harvesting, fruit setting per cent, length of fruit, diameter of fruit, and fruit weight were observed to be significant, with all levels of GA_3, over the control. The application of GA_3@75 ppm being at par with GA_3@50 ppm recorded maximum flowering and fruiting. Similar results were reported by Singh *et al*. (2019). The more number of flowers/cluster might have been due to more production of flower primordia by GA_3 (Ujjawal *et al*., 2018). The GA_3 might have become more active with extra food reserve, and hence the number of fruits seems to have increased. Besides, the rapid and better nutrient translocation from roots to apical parts of plants makes treated plants physiologically more active, resulting in more flowers and fruit setting. The increased fruit length and diameter might have been due to cell division and multiplication in reproductive organs. The increase in fruit weight might be due to deviation of a major portion of photosynthates from vegetative parts to reproductive ones by GA_3.

The number of flowers/cluster at 75 DAT, number of fruit clusters/plant at final harvesting, number of fruits/cluster, fruit setting, length of fruit, and diameter of fruit were significant over control. The significantly maximum number of flowers/cluster at 75 DAT, length of fruit, and diameter of fruit were recorded with 4-CPA@75 ppm which was found at par to 4-CPA@50 ppm. Similar results were observed by Naz *et al*. (2020). The increased fruit length under the influence of PGRs was due to better vegetative growth and physiological activity, resulting in assimilation built-up in plants, ultimately increasing fruit length. Whereas, number of fruit clusters/plant at final harvesting, number of fruits/cluster, and fruit setting were highest with 4-CPA@25 ppm and it was at par with 4-CPA@50 ppm. Similar results were observed by Akhter *et al*. (2018). This could be attributed to potential of 4-CPA to check flowers and fruit drops. When general effects are examined, it will be seen that 4-CPA encouraged fruit formation even at high concentrations, with related side effects of deformation and parthenocarpy. The lower fruit weight under 4-CPA was attributed to fruit puffiness effect caused by to deforming effects of 4-CPA at higher levels.

Similarly, flowering and fruiting characteristics were significant with all levels of NAA over the control. The maximum number of flowers/cluster at 75 DAT, number of fruit clusters/plant at final harvesting, number of fruits/cluster, number of fruits/plant at final harvesting, fruit setting, length of fruit, diameter of fruit, and fruit weight was observed with NAA@75 ppm, and it was at par with NAA@50 ppm. Similar results were observed by Naz *et al*. (2020). Higher dry matter accumulation due to better photosynthetic and metabolic activities; and efficient nutrient uptake due to hormonal activity of PGR are directly reflected in more fruit clusters (Mahindre, 2017). The higher number of fruits/plant and cluster with NAA applications may be attributed to increased fruit setting and fruit retention. The increase in fruit weight with the application of NAA might be due to the accumulation of adequate photosynthates for developing bigger-sized fruits (Kiranmayi, 2014).

The quality parameters like TSS, acidity, ascorbic acid content, lycopene content, and firmness were influenced significantly by different levels of GA_3 (Table 1). The application of GA3@75 ppm recorded the significantly highest TSS content (5.41^{o}Brix), ascorbic acid (22.8 mg/100g), lycopene content (6.0 mg/100g), and fruit firmness (2.4 kg/cm^2) over the control. Similar results were reported by Naz *et al*. (2020) and Ranjeet *et al*. (2014). The increased TSS content could be due to enhanced leaf area and more carbohydrate production through photosynthesis process (Bhat *et al.*, 2021) and increase in fruit firmness may be due to higher juice content, increased amount of cellulose in cell wall of fruit. The application of GA_3 might have converted the fruit acids into sugar and its derivatives by reversal of glycolytic pathways which might have caused a significant decrease in acidity of

Table 1. Effect of different levels of GA_3, 4-CPA and NAA on quality parameters in tomato.

Treatment	TSS (°Brix)	Acidity (%)	Ascorbic acid (mg/100g)	Lycopene content (mg/100g)	Firmness (kg/cm²)
GA_3@25 ppm	3.83	0.54	18.7	5.5	1.8
GA_3@50 ppm	5.03	0.53	20.5	5.9	2.2
GA_3@75 ppm	5.41	0.52	22.8	6.0	2.4
4-CPA@25 ppm	3.78	0.51	17.1	4.9	1.7
4-CPA@50 ppm	4.77	0.49	16.7	4.6	2.3
4-CPA@75 ppm	5.22	0.47	16.1	4.4	2.6
NAA@25 ppm	3.96	0.51	18.6	5.4	1.5
NAA@50 ppm	4.62	0.48	19.4	6.0	1.7
NAA@75 ppm	4.75	0.46	19.7	6.5	1.8
Control (water spray)	3.45	0.48	16.7	5.0	1.4
SEm±	0.09	0.01	0.52	0.13	0.07
CD (p=0.05)	0.27	0.04	1.5	0.4	0.2

GA_3, Gibberellic Acid; 4-CPA, 4-Chlorophenoxy Acetic Acid; NAA, Naphthalene Acetic Acid

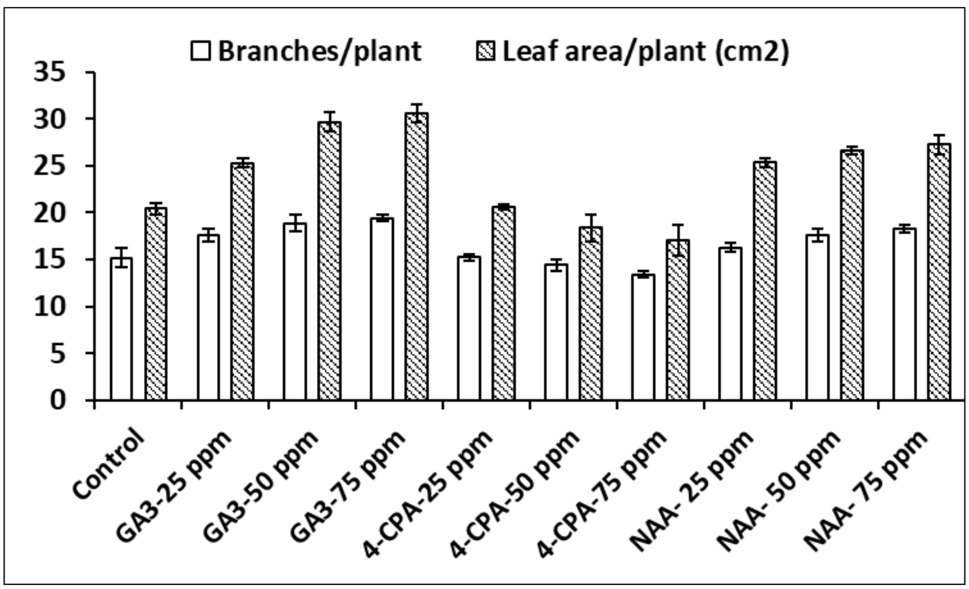

Fig. 1. Number of branches and leaf area/plant as influenced by different levels of gibbrellic acid, 4-CPA and NAA. The error bars represent the standard error.

tomato fruits and minimum acidity was recorded with GA3@75 ppm (0.47%). These results are in agreement with Ranjeet *et al*. (2014) and Naz *et al*. (2020).

Again, different levels of 4-CPA influenced significantly the TSS content and fruit firmness over control. The significantly maximum TSS content (5.22°Brix) and highest firmness (2.6 kg/cm²) over control was recorded in 4-CPA@75 ppm. This increase in fruit firmness may be due to higher juice content, increased amount of cellulose in the cell wall of the fruit, and therefore increased texture firmness (Weksler *et al.*, 2009).

The maximum TSS content (4.75 °Brix), ascorbic acid content (19.7 mg/100g), lycopene content (6.5 mg/100g), and fruit firmness (1.8 kg/cm²) were recorded over the control with NAA@75 ppm. This may be due to better root development, enhanced nutrient uptake, and better accumulation and translocation of photosynthates into fruits. Similar results were reported by Ahmed *et al.* (2019) in pepper.

CONCLUSION

The application of GA_3 at 75 ppm significantly increased plant height, branches, leaf area, and improving flowering and fruiting, enhancing fruit production and quality parameters. Application of NAA at 75 ppm showed comparable positive effects by increasing branches, leaf area, and fruit setting, leading to higher fruit yield with improved quality. Application of 4-CPA, though causing deformities at higher doses, had positive effects at lower concentrations on flowering and fruiting.

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