International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(10): 152-154
www.biochemjournal.com
Received: 17-08-2025
Accepted: 20-09-2025

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Effect of plant growth regulators on growth and yield attributes of tomato (*Solanum lycopersicum* L.)

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i10Sb.5830

Abstract
A grow-bag trial was conducted during the 2024-25 Kharif season at the Government Nursery, Mohgaon, Saja, Bemetara (Chhattisgarh), under the College of Horticulture and Research Station (CHRS), Saja, to evaluate the effect of foliar-applied gibberellic acid (GA_3) and naphthalene acetic acid (NAA) on tomato cv. Kashi Aman. Seven treatments (GA_3 at 75, 80, and 85 ppm; NAA at 90, 100, and 110 ppm; and an untreated control) were laid out in a completely randomized design with three replications and five 12 × 12 in. grow bags per replication. Sprays were applied at 20, 40, and 60 days after transplanting (DAT). Vegetative growth parameters (plant height, stem diameter, and number of branches) were recorded at 30, 45, 60, and 90 DAT, while reproductive responses (days to first flowering, fruits per cluster, fruits per plant, fruit-set percentage, average fruit weight, fruit diameter, and total yield per plant) were assessed at harvest. Foliar GA_3 at 85 ppm consistently produced the most vigorous plants (86.1 cm height, 11.7 mm stem diameter, 11.8 branches) and the earliest flowering (24.2 days). It also maximized yield components: 4.1 fruits per cluster, 20.1 fruits per plant, 83.1% fruit set, 68.2 g average fruit weight, 5.8 cm fruit diameter, and 1.40 kg yield per plant. GA_3 at 80 ppm and NAA at 110 ppm also significantly outperformed the control. These results demonstrate that foliar application of GA_3 at 85 ppm at critical growth stages markedly enhances vegetative vigor, reproductive success, and fruit yield of tomato. Future research should refine hormone dosages, application timing, and validate performance across field conditions and diverse cultivars.

Keywords: Tomato, GA_3, NAA, plant growth regulators, yield

Introduction

Tomato (*Solanum lycopersicum* L.) is a globally important vegetable crop, cultivated on over 5 million ha and yielding more than 189 million t annually. Its fruits are rich in water (93-95%), energy (18 kcal 100 g^{-1}), vitamin C (13-20 mg 100 g^{-1}), provitamin A (β-carotene 449 µg 100 g^{-1}), vitamin E, vitamin K, B-complex, minerals, and the antioxidant lycopene (3-7 mg 100 g^{-1}), which is linked to reduced cancer and cardiovascular risk (Giovannucci, 1999; Rai *et al*., 2011) [4, 13]. In India, tomato occupies 0.88 million ha with 20.7 million t production. In Chhattisgarh, it is grown on 38 500 ha, yielding 9.1 million t (23.6 t ha^{-1}) under both Kharif and Rabi seasons (NHB, 2023) [10]. Tomato productivity under tropical Kharif conditions often suffers from physiological disorders such as delayed flowering, poor fruit set, and premature fruit drop due to high temperatures and erratic rainfall during reproductive stages (Kumar *et al*., 2021; Verma *et al*., 2020) [7, 17]. These problems arise from insufficient endogenous gibberellins and auxins, which regulate cell division, floral organ differentiation, and sink strength in developing ovaries (Gustafson, 1960; Verma *et al*., 2020) [5, 17]. While Chhattisgarh's average tomato yield is close to the national mean, it remains far below the crop's potential, highlighting the need for region-specific trials in protected conditions to optimize hormonal interventions. Previous studies have shown that foliar applications of gibberellic acid (GA_3) and naphthalene acetic acid (NAA) enhance plant height, stem girth, branching, and yield in tomato. GA_3 at 50-100 ppm improved vegetative vigor and accelerated flowering (Naeem *et al*., 2001; Ayub and Rezende, 2010) [9, 1], while NAA at 75-150 ppm increased fruit set and retention by strengthening sink activity in developing ovaries (Banna *et al*., 2006; Mukati *et al*., 2019) [2, 8]. However, optimal concentrations and application timings under grow-bag cultivation—a system offering better control over root media and drainage—remain untested in Chhattisgarh's tropical wet-dry climate.

This study evaluates seven foliar treatments (GA_3 at 75, 80, 85 ppm; NAA at 90, 100, 110 ppm; and control) applied at 20, 40, and 60 DAT. By assessing vegetative (plant height, stem diameter, branches) and reproductive traits (flowering, fruit set, fruit size, yield), the study identifies the most effective PGR regime for maximizing tomato performance under protected grow-bag conditions.

Materials and Methods

The experiment was conducted during the 2024-25 Kharif season at the Government Nursery, Mohgaon, Saja, Bemetara (21.61° N, 81.29° E, 290 m amsl) under CHRS Saja in a completely randomized design (CRD). Treatments included: control, GA_3 at 75, 80, 85 ppm, and NAA at 90, 100, 110 ppm—each replicated three times with five 12 × 12 in. HDPE grow bags per replication. The medium consisted of field soil, vermicompost, and sand (3 : 1 : 1), analysed for texture, pH, EC, organic carbon, available N, P, and K. Seeds were raised in cocopeat : vermiculite : sand (1 : 1 : 1) protrays under 50% shade-net and transplanted at 28 days (4-5 true leaves). Spacing was 60 × 45 cm. At transplanting, each bag received 150 g FYM, 1.2 g urea, 6.7 g SSP, and 1.2 g MOP. Urea was split (0.6 g/bag) at 20, 40, and 60 DAT. Foliar micronutrients (0.5% Fe, Mn, B, Cu) were applied alternately. Irrigation was scheduled every 3-4 days, adjusted for rainfall. Pests and diseases were managed by recommended sprays. Foliar GA_3 and NAA sprays were applied to runoff at 20, 40, and 60 DAT in late afternoon. Five tagged plants per treatment were evaluated for vegetative traits (plant height, stem diameter, branches at 30, 45, 60, 90 DAT) and reproductive traits (days to first flowering, fruits per cluster, fruits per plant, fruit set%, fruit weight, fruit diameter, yield per plant). Data were analysed using ANOVA for CRD and treatment means compared with LSD at $p \leq 0.05$.

Results and Discussion

Foliar GA_3 and NAA significantly improved vegetative growth and yield of tomato cv. Kashi Aman under grow-bag culture. At 90 DAT, GA_3 at 85 ppm produced the tallest plants (86.09 cm), thickest stems (11.73 mm), and most branches (11.77), compared with the control (60.42 cm, 8.13 mm, 8.06 branches) (Table 1, Fig. 1). GA_3 at 80 and 75 ppm followed, while NAA treatments (90-110 ppm) gave moderate increases. Reproductive development was accelerated by GA_3, with flowering at 24.16 days (85 ppm) compared with 29.93 days in control (Table 1). Yield attributes improved significantly under GA_3 at 85 ppm: fruit set (83.05% vs 65.16%), fruits per plant (20.14 vs 14.27), fruits per cluster (4.12 vs 3.09), average fruit weight (68.20 g vs 58.93 g), and fruit diameter (5.82 cm vs 4.53 cm). Consequently, yield per plant rose to 1.40 kg, a 77% increase over control (0.79 kg) (Table 2, Fig. 2). NAA at 110 ppm also improved fruit set (76.54%), fruit weight (64.63 g), and yield (1.15 kg/plant), but was less effective than GA_3. The results confirm GA_3's role in promoting cell elongation, vascular differentiation, and assimilate partitioning, while NAA supported ovary retention and fruit set. A dose-dependent response was evident, with GA_3 at 85 ppm proving most effective under grow-bag conditions.

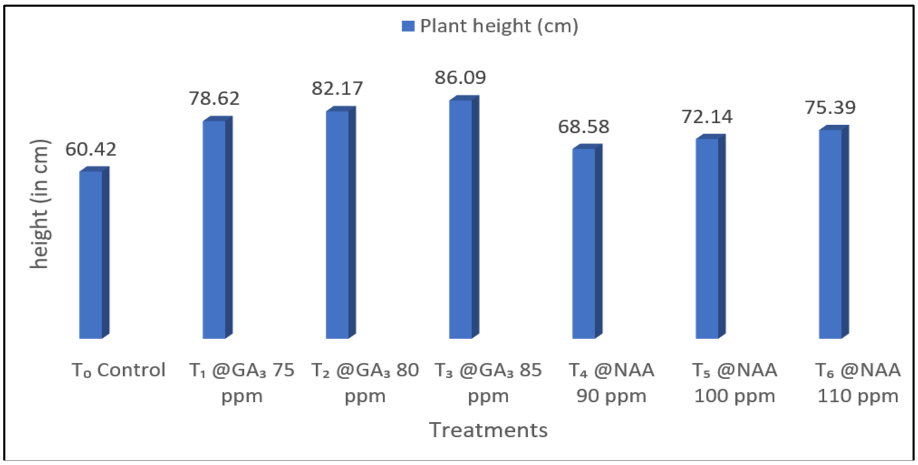

Fig 1: Effect of GA_3 and NAA concentrations on plant height of tomato cv. Kashi Aman at 90 DAT.

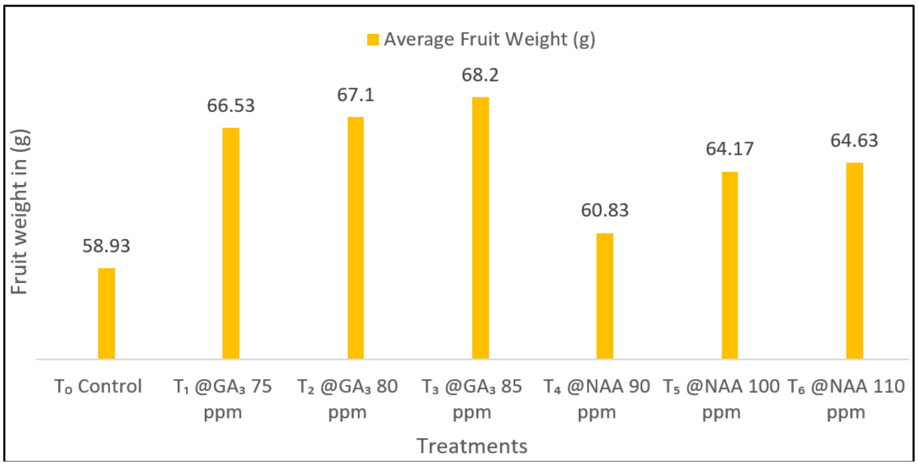

Fig 2: Effect of GA_3 and NAA concentrations on average fruit weight of tomato cv. Kashi Aman at harvest.

Table 1: Effect of GA_3 and NAA on growth attributes of tomato cv. Kashi Aman.

Treatments	Plant height (cm)	Stem diameter (mm)	No. of branches	Days to first flowering
T_0 Control	60.42	8.13	8.06	29.93
T_1 @ GA_3 75 ppm	78.62	10.69	10.47	26.37
T_2 @ GA_3 80 ppm	82.17	11.55	11.24	25.84
T_3 @ GA_3 85 ppm	86.09	11.73	11.77	24.16
T_4 @ NAA 90 ppm	68.58	8.96	9.43	31.41
T_5 @ NAA 100 ppm	72.14	9.79	10.08	32.28
T_6 (@ NAA 110 ppm	75.39	10.25	10.45	33.53
SEM±	2.61	0.29	8.06	0.76
CD	7.90	0.89	10.47	2.31

Table 2: Effect of GA_3 and NAA on yield attributes of tomato cv. Kashi Aman.

Treatments	No. of Fruits per Plant	No. of Fruits per Cluster	Fruit Set (%)	Average Fruit Weight (g)	Total Yield per Plant (kg)	Fruit Diameter (cm)
T_0 Control	14.27	3.09	65.16	58.93	0.79	4.53
T_1 @ GA_3 75 ppm	17.38	3.41	78.01	66.53	1.11	5.18
T_2 @ GA_3 80 ppm	18.47	3.82	80.42	67.10	1.29	5.47
T_3 @ GA_3 85 ppm	20.14	4.12	83.05	68.20	1.40	5.82
T_4 @ NAA 90 ppm	15.09	3.17	70.47	60.83	0.94	4.76
T_5 @ NAA 100 ppm	16.34	3.34	73.28	64.17	1.02	5.03
T_6 (@ NAA 110 ppm	17.51	3.69	76.54	64.63	1.15	5.34
SEM±	2.70	0.16	2.40	2.94	0.05	0.16
CD	0.89	0.48	7.27	6.31	0.17	0.49

Conclusion

Foliar application of GA_3 and NAA enhanced tomato growth and productivity under protected grow-bag culture at CHRS Saja. GA_3 at 85 ppm produced the highest vegetative vigor, earliest flowering, and maximum yield, outperforming all other treatments. NAA at 110 ppm showed moderate benefits but was inferior to GA_3. Thus, GA_3 at 85 ppm, applied at 20, 40, and 60 DAT, is recommended for maximizing tomato yield under similar cultivation systems.

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