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Investigating the Effect of Plant Growth Regulators on Growth, Yield and Quality of Chilli (*Capsicum annuum* L.)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The present investigation was carried out at the Central Research Farm, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture Technology and Sciences, Prayagraj, Uttar Pradesh during *Kharif* 2022-23 to identify the effects of different doses plant growth regulators and its role in growth, yield and quality of Chilli variety TMPH-409. The experiment was laid in Randomized block design with 19 treatments and 3 replications with different combination in plant growth regulators. Under this experiment, overall, 19 treatment was taken including control. Different plant growth regulators (PGRs) used comprised of NAA, GA_3, 2-4 D, all four at different doses. According to the current research, the use of Plant growth regulators (PGRs) had a significantly positive impact on the growth and development of chilies. Among the various treatments that were evaluated, T_7 yielded the most favourable results in terms of growth viz., plant height (88.06 cm at 90 DAT), number of primary branches (9.97 branches at harvest), leaf area (192.78 cm^2), early days to 50% flowering (64.94 DAT) and yield viz., fruit weight (3.71 g), length of fruit (7.96 cm), fruit girth (3.00 cm), number of fruits per plant (251.62 fruits), and yield per plant (878.93 g/plant). T_7 consisted of NAA at 40 ppm + GA_3 at 100 ppm.

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1. INTRODUCTION

Chilli (vernacular name: Mirchi), botanically known as *Capsicum annuum* (L.) is one of the well-known plants belonging to Solanaceae. It is a diploid cross-pollinated dicot plant species with chromosome number 2n=2x=24 [1]. Capsicum plants originated in modern-day Bolivia and have been a part of human diets since about 7,500 BC [2]. They are one of the oldest cultivated crops in the Americas. Origins of cultivating chili peppers have been traced to east-central Mexico some 6,000 years ago, although, according to research by the New York Botanical Garden press in 2014, chili plants were first cultivated independently across different locations in the Americas including highland Bolivia, central Mexico, and the Amazon (Katherine, 2014). They were one of the first self-pollinating crops cultivated in Mexico, Central America, and parts of South America. In India Chilli is grown in Andhra Pradesh, Telangana, Madhya Pradesh, Karnataka, West Bengal, and Himachal Pradesh on large scale. The substances that give chili peppers their pungency (spicy heat) when ingested or applied topically are capsaicin (8-methyl-N-vanillyl-6-nonenamide) and several related chemicals, collectively called capsaicinoids. The quantity of capsaicin varies by variety, and on growing conditions. Water-stressed peppers usually produce stronger pods. When a plant is stressed, by absorbing low water for example, the concentration of capsaicin increases in some parts of the fruit (Ruiz-Lao, 2011). The varieties of chilies that are cultivated in India are Naga, Jwala, Guntur, Kanthari, Bhut Jolokia and many more. Lycopene, which is soluble in water, is responsible for the red colour of red chili peppers.

PGRs have been found to alleviate the adverse effects of various abiotic stresses on chilli plants, including drought, salinity, and extreme temperatures. They can enhance stress tolerance and improve the plant's ability to withstand challenging environmental conditions [3]. Auxins like NAA, are commonly used as rooting hormones during propagation, leading to improved root establishment and overall plant vigour [4]. Gibberellic acid (GA) and cytokinin can stimulate flowering and increase fruit set in chilli plants. They can help in synchronizing flowering, resulting in uniform fruit production and higher yields [5]. Plant growth regulators (PGRs) are crucial for the growth and development of chilli plants. They promote cell division, elongation, and differentiation, leading to better plant growth, flowering, fruiting, and seed formation. PGRs can also enhance nutrient uptake efficiency, increase resistance to biotic and abiotic stresses, and improve crop quality and yield. In chilli cultivation, PGRs like gibberellic acid (GA_3) and salicylic acid can improve plant vigour and health, synchronize maturity, promote fruit set, and increase marketable yield, thereby increasing profitability. The use of PGRs is a valuable tool for growers to maximize crop potential and meet consumer demand. Keeping these above point the present investigation was undertaken with aim to study the effect of plant growth regulators on growth, yield and quality of Chilli.

2. MATERIALS AND METHODS

The present investigation was done to understand the impact of combine application and sole application of plant growth regulators on plant growth, fruit yield and quality of fruit of chilli variety TMPH-409. The details of the materials used, and the methods adopted in the investigation, which was carried out at Horticultural Research Field (HRF), Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj during the *Kharif* season of 2022. The experiment was laid in Randomized block design with 19 treatments and 3 replications with different combination in plant growth regulators. Observations were recorded at different stages of growth periods and studied for growth parameters like plant height, number of branches per plant, leaf area, earliness parameters like days to 50% flowering, days to first fruit picking, yield parameters like fruit length, fruit girth, fruit weight and quality parameters TSS and vitamin C content. The data were analysed by the method suggested by Fisher and Yates, 1963. The height of five randomly selected plants from each plot was measured in cm with of a 100 cm meter scale from ground level to tip of the shoot at 90 DAT stage. The numbers of branches per plant (plant) of five randomly selected plants arising from main shoot were counted and were averaged to represent numbers of primary branches per plant. Number of branches per plant basis was counted at harvest stage. The numbers of days taken from the date of sowing to the date at which first flower appeared in plants or date at which plants start flowering in whole plot were recorded as days to first flowering, similarly, was taken for days to first flowering and days to first fruit harvest. The percentage of total soluble solids of the fruit was determined with the help of Portable Hand Refractometer. The sample of juice for this purpose was taken from the strained juice. The observed value of T.S.S. was recorded from the scale of the instrument (0-32 range). Vitamin C content or Ascorbic acid content in the pulp was estimated by using 2, 6 dichlorophenol indophenol dye as reported by Ranganna (1986).

The details of treatment combination used are $\mathbf{T_0}$ (Water Spray (Control)); $\mathbf{T_1}$ (NAA at 40 ppm); $\mathbf{T_2}$ (NAA at 60 ppm); $\mathbf{T_3}$ (GA_3 at 100 ppm); $\mathbf{T_4}$ (GA_3 at150 ppm); $\mathbf{T_5}$ (2,4-D at 5 ppm); $\mathbf{T_6}$ (2,4 D at 7.5 ppm); $\mathbf{T_7}$ (NAA at 40 ppm + GA_3 at 100 ppm); $\mathbf{T_8}$ (NAA at40 ppm + GA_3at150 ppm); $\mathbf{T_9}$ (NAA at60 ppm + GA_3 at 100 ppm); $\mathbf{T_{10}}$ (NAA at 60 ppm + GA_3 at 150 ppm); $\mathbf{T_{11}}$ (NAA at 40 ppm + 2,4 D at 5 ppm); $\mathbf{T_{12}}$ (NAA at40 ppm + 2,4 D at 7. 5 ppm); $\mathbf{T_{13}}$ (NAA at 60 ppm + 2,4 D at 5 ppm); $\mathbf{T_{14}}$ (NAA at 60 ppm + 2,4 D at 7.5 ppm); $\mathbf{T_{15}}$ (GA_3 at 100 ppm + 2,4 D at 5 ppm); $\mathbf{T_{16}}$ (GA_3 at 100 ppm + 2,4 D at 7.5 ppm); $\mathbf{T_{17}}$ (GA_3 at150 ppm + 2,4 D at 5 ppm); $\mathbf{T_{18}}$ (GA_3 at 150 ppm + 2,4 D at 7.5 ppm).

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Influence of Plant growth regulators (PGRs) on Plant height (cm)

The maximum plant height at 90 DAT (88.06 cm) was observed with treatment T_7 (NAA at40 ppm + GA_3 at100 ppm). Minimum plant height at 90 DAT (72.76 cm) was observed in T_0 (Control) while the remaining treatments were moderate in their growth habit. PGRs application regulates plant height in chilli by influencing cell division and elongation, promoting internode elongation, and altering hormonal balance. Specific PGRs, such as gibberellic acid (GA_3), can stimulate stem elongation and increase plant height. Similar findings were reported by Kannan et al. [6]; Mahato et al. [7]; Kumar et al. [8] and Kumar and Topno [9].

3.1.2 Influence of Plant growth regulators (PGRs) on number of branches per plant

The maximum number of primary branches per plant at 90 DAT (9.97 branches) was observed with treatment T_7 (NAA at40 ppm + GA_3 at100 ppm). Minimum number of primary branches per plant at 90 DAT (6.33 branches) was observed in T_0 (Control). PGRs application regulates the number of branches in chilli by influencing axillary bud development and branching patterns. Certain PGRs, promotes lateral bud growth and increase the number of branches. By manipulating hormonal signals and bud activation, PGRs play a crucial role in controlling the branching architecture of chilli plants and determining the number of branches they produce. Similar findings were reported by Kumar et al. [10,11]; Tayde et al. [12]; and Kumar and Topno [9].

3.1.3 Leaf area (cm^2)

The maximum Leaf area at flowering (192.78 cm^2) was observed with treatment T_7 (NAA at40 ppm + GA_3 at100 ppm). Minimum Leaf area at flowering (117.65 cm^2) was observed in T_0 (Control) while the remaining treatments were moderate in their growth habit. PGRs application regulates leaf area in chilli by stimulating leaf expansion and increasing leaf size. Certain PGRs, such as auxins and gibberellins, promote cell division and elongation, resulting in larger leaf size and overall increased leaf area in chilli plants. Similar findings were reported by Ahmadi and Majidi [13] in tomato; Tayde et al. [12]; Mishra et al. [14]; Kannan et al. [6].

3.2 Earliness Parameter

3.2.1 Influence of Plant growth regulators (PGRs) on Days to first flowering and days to first fruit harvest

The minimum days to first flowering at flowering (36.83 days) was observed with treatment T_7 (NAA at40 ppm + GA_3 at100 ppm). Maximum days to first flowering at flowering (45.62 days) was observed in T_0 (Control). The minimum days to first harvest at flowering (64.94 days) was observed with treatment T_7 (NAA at40 ppm + GA_3 at100 ppm). Maximum days to first harvest at flowering (78.88 days) was observed in T_0 (Control). PGRs application regulates early flowering and maturity in chilli by influencing flowering hormone levels and accelerating reproductive development. PGRs, such as gibberellins can promote flower bud initiation, shorten the time to flowering, and facilitate early fruit set and maturation, leading to an expedited flowering and maturity process in chilli plants. Similar conclusions were inferred by Farooq et al. [15] in tomato; Mishra et al. [14]; Kannan et al. [6]; Mahato et al. [7].

Table 1. Effect of PGRs on different treatments for various parameters of chilli

Treatment Notation	Plant height (cm) [at 90 DAT]	No of branches per plant [at first Harvest]	Leaf area (cm^2)	Days to first flowering	Days to first fruit harvest	No of fruits per plant	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Fruit yield per plant (g/plant)	TSS [°Brix]	Ascorbic acid content (mg/100g)
T_0	72.76	6.33	117.65	45.62	78.88	90.36	4.55	1.33	2.11	190.66	3.22	1.40
T_1	79.73	7.62	136.16	42.76	71.30	114.02	6.02	1.86	2.57	321.61	3.69	1.79
T_2	79.69	7.45	135.79	43.32	71.41	107.46	5.98	1.74	2.56	318.55	3.62	1.69
T_3	79.82	7.77	137.79	42.74	71.08	120.42	6.60	2.10	2.63	324.85	3.77	1.79
T_4	78.93	6.77	119.79	44.24	72.30	94.29	5.91	1.54	2.52	313.26	3.50	1.67
T_5	79.15	7.45	179.78	43.63	71.43	97.19	5.96	1.60	2.52	314.81	3.57	1.67
T_6	74.00	6.42	119.16	44.28	72.95	91.98	4.91	1.54	2.12	194.49	3.45	1.41
T_7	88.06	9.97	192.78	36.83	64.94	251.62	7.96	3.00	3.71	878.93	4.28	2.15
T_8	85.80	8.97	181.58	38.65	66.97	220.62	7.45	2.82	3.32	622.65	4.04	1.89
T_9	82.62	8.65	167.52	41.24	69.35	182.62	7.34	2.78	2.86	469.58	3.89	1.85
T_{10}	81.75	8.57	161.72	41.43	69.54	155.89	7.29	2.76	2.81	461.60	3.88	1.84
T_{11}	86.88	9.78	183.89	37.27	66.76	228.37	7.51	2.84	3.33	647.57	4.10	2.02
T_{12}	80.80	7.85	156.59	42.41	70.66	136.22	6.94	2.13	2.72	372.62	3.82	1.79
T_{13}	81.00	8.57	160.40	41.46	69.57	148.70	7.09	2.76	2.74	418.16	3.85	1.80
T_{14}	80.79	7.85	141.29	42.55	70.87	125.62	6.68	2.12	2.68	343.43	3.80	1.79
T_{15}	86.96	9.96	190.60	37.24	65.38	245.54	7.55	2.85	3.58	794.51	4.11	2.13
T_{16}	84.04	8.85	169.48	39.95	68.28	186.64	7.38	2.79	3.01	495.28	3.91	1.87
T_{17}	85.73	8.97	179.78	38.86	67.15	200.13	7.40	2.81	3.20	602.93	3.99	1.89
T_{18}	85.30	8.85	177.20	39.04	68.06	192.91	7.40	1.74	3.15	551.18	3.94	1.87
F test	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
S.E (d) (±)	**1.41**	**0.24**	**0.37**	**0.99**	**1.02**	**5.59**	**0.49**	**0.34**	**0.40**	**6.75**	**0.13**	**0.21**
$CD_{0.05}$	**2.86**	**0.50**	**0.76**	**2.00**	**2.08**	**11.37**	**1.00**	**0.69**	**0.80**	**1.37**	**0.25**	**0.43**
C.V.	**2.10**	**3.59**	**0.29**	**2.95**	**1.80**	**4.25**	**8.81**	**17.45**	**16.76**	**17.68**	**3.99**	**14.30**

3.3 Yield Parameters

3.3.1 Influence of Plant growth regulators (PGRs) on number of fruits per plant

The maximum number of fruits per plant at flowering (251.62 fruits) was observed with treatment T_7 (NAA at40 ppm + GA_3 at100 ppm). Minimum number of fruits per plant at flowering (90.36 fruits) was observed in T_0 (Control). PGRs application enhances the number of fruits per plant in chilli by stimulating flower initiation, improving pollination and fertilization, and increasing fruit set. PGRs, such as auxins promote flower bud differentiation, enhance flower viability, and ultimately contribute to an increased yield of fruits per plant in chilli crops. Similar conclusions were inferred by Mahato et al., [7]; and Kumar and Topno [9].

3.3.2 Influence of Plant growth regulators (PGRs) on fruit length (cm) and fruit girth (cm)

The maximum average fruit length at flowering (7.96 cm) was observed with treatment T_7 (NAA at40 ppm + GA_3 at100 ppm). Minimum average fruit length at flowering (4.55 cm) was observed in T_0 (Control). The maximum average fruit girth at flowering (3.00 cm) was observed with treatment T_7 (NAA at40 ppm + GA_3 at100 ppm). Minimum average fruit girth at flowering (1.33 cm) was observed in T_0 (Control). PGRs application regulates the enhancement of fruit length and fruit girth in chilli by influencing cell division and expansion processes. PGRs, such as gibberellins and auxins, promote cell elongation, increase fruit size, and stimulate fruit development, resulting in larger and more substantial fruits in terms of length, girth, and diameter in chilli plants. These results are in close conformity with the findings of Kumar et al. [10,11]; Mishra et al. [14].

3.3.3 Influence of Plant growth regulators (PGRs) on fruit weight (g) and fruit yield per plant (g/plant)

The maximum average fruit weight at flowering (3.71 g) was observed with treatment T_7 (NAA at40 ppm + GA_3 at100 ppm). Minimum average fruit weight at flowering (2.11 g) was observed in T_0 (Control). The maximum fruit yield per plant at flowering (878.93 g/plant) was observed with treatment T_7 (NAA at40 ppm + GA_3 at100 ppm). Minimum fruit yield per plant at flowering (190.66 g/plant) was observed in T_0 (Control). PGRs application regulates the enhancement of fruit weight and yield in chilli through multiple mechanisms. PGRs, such as gibberellins and auxins promote cell division, elongation, and expansion, leading to increased fruit size and weight. They also enhance nutrient uptake, photosynthesis, and carbohydrate partitioning, providing the necessary resources for fruit development. Additionally, PGRs can improve flower initiation, pollination, and fruit set, ensuring a higher number of fruits per plant, ultimately resulting in enhanced fruit weight and overall yield in chilli crops. Similar inferences were also concluded by Kumar and Topno [9].

3.4 Quality Parameters

3.4.1 Influence of Plant growth regulators (PGRs) on TSS (° Brix)

The maximum TSS at flowering (4.28 °Brix) was observed with treatment T_7 (NAA at40 ppm + GA_3 at100 ppm). Minimum TSS at flowering (3.22 °Brix) was observed in T_0 (Control). Similar inferences were also concluded by Ahmadi and Majidi [13] in tomato; Arivazhan et al. [16] in brinjal; Kumar et al. [10,11]; Kumar et al. [8,9].

3.4.2 Influence of plant growth regulators (PGRs) on Ascorbic Acid (mg/100g)

The maximum ascorbic acid content at flowering (2.15 mg/100g) was observed with treatment T_7 (NAA at40 ppm + GA_3 at100 ppm). Minimum ascorbic acid content at flowering (1.40 mg/100g) was observed in T_0 (Control). Similar inferences were also concluded by Kumar et al. [10,11]; Mahato et al. [7]; Kumar et al. [8,9], [17].

4. CONCLUSION

According to the current research, the use of Plant growth regulators (PGRs) had a significantly positive impact on the growth and development of chilies. Among the various treatments that were evaluated, T_7 yielded the most favourable results in terms of growth viz., plant height (88.06 cm at 90 DAT), number of primary branches (9.97 branches at harvest), leaf area (192.78 cm^2), early days to 50% flowering (64.94 DAT) and yield viz., fruit weight (3.71 g), length of fruit (7.96 cm), fruit girth (3.00 cm), number of fruits per plant (251.62 fruits), and yield per plant (878.93 g/plant). T_7 consisted of NAA at 40 ppm + GA_3 at 100 ppm.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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