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Influence of different plant growth regulators on growth, yield and quality characteristics of cucumber (*Cucumis sativus* L) cv. Kashi Nutan

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Abstract
The study titled "Influence of Different Plant Growth Regulators on Growth, Yield and Quality Characteristics of Cucumber (*Cucumis sativus* L.) cv. Kashi Nutan" was conducted at the Horticultural Field, Udai Pratap Autonomous College, Varanasi, during the 2024 summer season using a Randomized Block Design with nine treatments and three replications. The experiment aimed to assess the effects of plant growth regulators on cucumber growth, yield, and quality. The treatments consisted of three growth regulators *viz*., Gibberellic acid (50 and 100 ppm), Naphthalene acetic acid (50 and 100 ppm), Ethrel (50 and 100 ppm) and their combining combination (GA3 50 ppm + NAA 100 ppm and GA3 50 ppm + Ethrel 100ppm) with a control applied to assess their impact on cucumber growth, yield and quality. Results showed that the application of GA_3 50 ppm + NAA 100 ppm led to the highest growth parameters, including vine length, number of branches, and leaves, along with maximum fruit number, size, and yield. Application of GA_3 100 ppm showed the shortest time to flowering and the highest Total Soluble Solids (TSS) and ascorbic acid content. The control treatment recorded the lowest values for all measured parameters.

Keywords: Kashi Nutan, Cucumber, GA3, NAA, Gibberellic, Ethrel, measured parameters

Introduction
Vegetables are rich in essential vitamins and minerals that promote good health, with key vitamins like A, B, C, D, and E found in various crops. The ICMR recommends consuming 300 grams of vegetables daily, including green leafy, root, and other types of vegetables. Cucumber originated in India, particularly in the Himalayan foothills, and was domesticated 3,000 years ago. Although widely cultivated worldwide, it remains underutilized in terms of economic and breeding potential, especially in India, despite its significant diversity and importance in the Cucurbitaceae family. Cucumber (*Cucumis sativus* L.) is one of the oldest cultivated vegetables, originating from India, and is valued for its cooling properties and nutritional content, including minerals, thiamine, niacin, and vitamin C. The fruit is 95% water, with small amounts of protein, fat, carbohydrates, and fiber, and is commonly used as a vegetable or in salads (Kathayat *et al*., 2018) [9]. Cucumber sex expression is influenced by genetics and environmental factors like photoperiod and temperature, with plant growth regulators (PGRs) playing a crucial role. These bio-stimulants or inhibitors regulate plant metabolism, and their proper application can modify sex expression, promoting more pistillate flowers and enhancing yield in cucumbers. Plant growth regulators significantly impact physiological and biochemical processes in plants, managing cucumber vegetative growth to increase plant density and productivity. Naphthalene Acetic Acid (NAA) is a key regulator used to modify growth patterns, improve yield, and influence yield-related factors in Cucurbitaceae crops. (Alotaibi *et al* 2024) [1]. The manipulation of cucumber flower sex ratios through plant growth regulators was first reported by Laibach and Kribben in 1950. Subsequent studies from the USA, Japan, Israel, and India, including work by Bhandary *et al*. (1974) [2], explored the effects of various chemicals like MH, NAA, IAA, TIBA, and GA. These chemicals, applied as foliar sprays on cucumbers, watermelon, and bottle gourd, were shown to effectively alter the sex ratio, promoting female flower production and increasing yield (Matlob and Basher, 1982) [12]. Ethrel (Ethephon), an ethylene-releasing compound, was also found to increase pistillate (female) flowers.

(Loy, 1971) [10]. Plant growth regulators such as GA_3, NAA, and Ethrel have been shown to influence sex expression in cucurbits, either by suppressing male flowers or increasing female flower numbers. This has been observed in studies by Hussain *et al*. (2012) [11] on bottle gourd, Dalai *et al*. (2015) [4] on cucumber, on bitter gourd, on cucumber. These regulators reduce male flower production on lateral branches, ultimately boosting yield. However, limited information is available regarding their overall impact on cucumber growth, flowering, sex expression, and yield. Thus, the current study was conducted to determine the different levels of various plant growth regulators (NAA, GA3 and Ethrel) on the growth, yield and quality of cucumber.

Materials and Methods

The experiment was conducted at the Horticultural field. Department of Horticulture, Udai Pratap Autonomous College, Varanasi during summer season 2023-24. The experiment utilizing a randomized block design (RBD) with three replications, the experiment tested nine different treatments. Each treatment was randomly allocated to plots within each block. The treatments comprised three different combinations of PGRs i.e.T_1-GA3 50 ppm, T_2-GA3 100 ppm, T_3-NAA 50 ppm, T_4-NAA 100 ppm, T_5-Ethrel 50 ppm, T_6-Ethrel 100 ppm, T_7-GA3 50 ppm + NAA 100 ppm, T_8-GA3 50 ppm + Ethrel 100 ppm and T_9-control.During land preparation, 12 tonnes of farmyard manure per hectare were applied, along with a basal dose of fertilizers i.e.,50 kg nitrogen, 80 kg phosphorus, and 60 kg potassium per hectare. An additional 50 kg of nitrogen was top-dressed at 30 days after seed dibbling, following IIVR Varanasi's recommendations. A stock solution of GA_3 was prepared by dissolving 1 g of GA_3 in 50 ml ethyl alcohol, then adding 950 ml of distilled water to make a 1000 ppm concentration. This stock solution was then diluted to prepare 50 ppm and 100 ppm solutions for spraying treatments. A stock solution of NAA was prepared by dissolving 1 g of NAA and 2 g of $NaHCO_3$ in 10 ml of ethyl alcohol, then adding distilled water to make 1 litre for a 1000 ppm concentration. This solution was diluted to 50 ppm and 100 ppm as needed, with fresh stock prepared at the time of spraying. A stock solution of Ethrel was prepared by dissolving 2.5 ml of Ethrel in 1000 ml of distilled water to achieve a 1000 ppm concentration. This stock solution was then used to prepare 50 ppm and 100 ppm solutions for spraying treatments. Plant growth regulators were applied as a foliar spray using a hand sprayer during the two to four leaf stages, with precautions taken to avoid cross-contamination between treatments. The sprayer was thoroughly washed with distilled water before each subsequent treatment to ensure accuracy and prevent interference.

Results and Discussion

All the growth attributes such as vine length, number of branches, number of nodes and number of leaves per plant are variably affected by with the application of PGRs which are represented in Table 1. The experimental findings showed that all growth parameters were significantly enhanced by using increasing concentrations of GA3 and NAA. However, a combined application of GA3 and NAA proved to be more effective than the control and other treatments throughout the experiment. In the current study, the combined application of GA_3 (50 ppm) and NAA (100 ppm) resulted in the maximum vine length of 130.44 cm, closely followed by application of GA_3 (100 ppm) alone, yielding a vine length of 128.89 cm. This enhanced vine growth due to the combination of GA_3 and NAA aligns with the findings of Dalai *et al.* (2015) [4], who explained that GA_3 and NAA promote elongation of branches by increasing internode length. The exogenous application of these regulators enhances the endogenous levels of GA_3 and NAA, providing additional growth stimulation in cucumber. These results are consistent with previous research by Dalai *et al.* (2015) [4] and Gosai *et al.* (2020) [6], who reported similar outcomes in cucumber growth.

In this study, the application of GA3 50 ppm + NAA 100 ppm resulted in the highest number of branches per vine i.e., 6.78 followed by GA3 (100 ppm) i.e., 6.41, while the control group had the fewest branches. The increase in branching is attributed to the positive effects of GA3 and NAA on cell elongation. This result aligns with the findings of Dalai *et al*. (2015) [4] in cucumbers. Additionally, also reported an increase in branch numbers with GA3, and Kadi *et al*. (2018) [7] found that GA3 at 100 ppm enhanced growth parameters, supporting these observations.

Similarly, the highest average number of nodes per plant (4.66) was observed with the combined application of GA3 50 ppm + NAA 100 ppm, followed by GA3 100 ppm (21.67) and GA3 50 ppm (20.44), while the lowest (16.56) was recorded under the control. The significant results may be attributed to the reversible effect of GA3 and NAA on mitosis, leading to a greater number of nodes on stem of cucumber plants. Similar findings were reported by researchers such as Dalai *et al*. (2015) [4].

The number of leaves per plant varied significantly across all treatments and showed a considerable increase due to the combined application of plant growth regulators at all stages of growth. The experimental results revealed that the highest number of leaves (48.67) was observed with the combination of GA3 50 ppm + NAA 100 ppm, while the lowest (38.45 leaves per plant) was recorded under the control. Leaves play a crucial role in various metabolic processes in plants, such as photosynthesis, respiration, transpiration, and nutrient translocation. The increase in leaf number may be attributed to the additional availability of gibberellins in the seeds, which likely boosted the amylase levels in the aleurone layer, facilitating the conversion of complex starches into sugars, providing energy for growth. These internal processes are responsible for the formation of more leaves in cucumber plants. These findings align closely with the results reported by Katta and Deepanshu (2023) [8].

Effect of PGRs on phenological attributes on cucumber

The effects were observed in several aspects, including the days to first flower formation, the number of male and female flowers per plant, and the sex ratio. Different treatments showed significant variation in the time taken for the first flower (male/female) to appear. The application of GA3 100 ppm was the most effective in reducing the time to first flower formation (32.32 days/36.20 days), followed by GA3 50 ppm + NAA 100 ppm (33.10 days/37.66 days). In contrast, the control group took the longest to flower (41.04 days/46.24 days). The variation in days to first flower formation may be attributed to the impact of plant growth regulators (PGRs) in the different treatments. In this study, growth regulators promoted the earlier initiation of male and female flowers, likely due to increased metabolization of GA3 in plants, which reduced sugar levels and altered membrane permeability. These findings align with Gedam *et al*. (1998), who reported that GA3 at 35 ppm led to the earliest male flower initiation in bitter gourd, and with similar results observed by Farhana (2015) in cucumber.

In reference of sex ratio, data clearly demonstrated in table number 1 that the effects of different growth regulators, such as PGRs, on the male-to-female sex ratio varied significantly. Among all treatments, the application of Ethrel 100 ppm proved most effective in maintaining the sex ratio, followed by combination of GA3 50 ppm+ Ethrel 100 ppm, as compared to the control and other treatments. The highest male-to-female ratio (2.66) was observed in the control, while the lowest ratio (1.72) was achieved with the dose of Ethrel 100 ppm. The combined application of Ethrel at optimal doses may have led to a reduction in male (staminate) flowers and an increase in female (pistillate) flowers. The narrower sex ratio achieved with the application of Ethrel could be due to the reported effects of these substances in promoting functional female organs, enhancing compatibility, and reducing embryo abortion in plants. These findings are in agreement with the results reported by the Patel *et al*. (2019) [5] are in accordance with the result of present investigation.

Effect of PGRs on fruits and yield attributes of cucumber

The data for different treatments, in terms of fruit length, number of fruits, fruit diameter and fruit weight) are summarized in Table 3. All the fruit attributes such as fruit length, number of fruits, fruit diameter and fruit weight were highest observed in treatment with the application of GA3 @ 50 ppm + NAA 100 ppm), with values of 19.55 cm, 18.32 fruits/plants, 4.99 cm and 139.08 g respectively. In contrast, the lowest values were observed in Control, with of fruit length, number of fruits, fruit diameter and fruit weight recorded at 14.78 cm, 15.77 fruits/plants, 3.65 cm and 110.24 g, respectively. It may be explained as that sole function of fertilized ovules or seeds in relation to growth of fruit are to synthesize one or more hormone, which initiate and maintain a metabolic gradient along with food that can be transferred from parts of plants towards the fruits. The result was supported by finding of Dalai *et al*. (2015) [4] reported that the application of GA3 20 ppm + NAA 100 ppm produces significantly maximum length of fruit in cucumber.

The highest fruit yield per plant (2.51 kg) was observed with the combined application of GA_3 50 ppm + NAA 100 ppm, followed by GA_3 100 ppm (2.38 kg), and GA_3 50 ppm + Ethrel 100 ppm (2.30 kg). In contrast, the lowest fruit yield per plant (1.82kg) was recorded in the control group. These results also reflected on the total yield per plot of tender green cucumber, with the highest yield per plot (15.18 kg) achieved using GA_3 50 ppm + NAA 100 ppm, and the lowest yield per plot (10.98 kg) found in the control group. Table 2 clearly shows that the application of different plant growth regulators, such as GA_3 and NAA, significantly enhanced cucumber yield compared to the control. The maximum fruit yield (167.33q/ha) was obtained with the combined foliar application of GA_3 50 ppm + NAA 100 ppm, followed by GA_3 at 100 ppm (158.66 q/ha) and GA_3 50 ppm + Ethrel 100 ppm (153.33 q/ha). The lowest yield (121.99 q/ha) was recorded in the control group. The increased fruit yield in treated plants may be due to their enhanced physiological activity, which helps in supporting flower and fruit development, leading to higher yields, as also reported by Imamsaheb and Hanchimani (2014). Similar findings were observed by Pandey *et al*. (2021) [13].

Effect of PGRs on quality parameters of cucumber

The results presented in Table 4 indicate significant variations in total soluble solids (TSS) and vitamin C content among the individual as well as combination of PGRs. The highest TSS was observed with the application of GA3 100 ppm i.e., 4.57 °Brix, followed by GA3 50 ppm+ NAA 100 ppm i.e., 4.34 °Brix, while the lowest TSS recorded in the control i.e., 2.52 °Brix. This increase in TSS with GA_3 application might be attributed to the enhanced metabolic conversion of starch, a trend also noted by Kadi *et al*. (2018) [7], Pandey *et al*. (2020) [13], Katta and Deepanshu (2023) [8] who also noted that GA3 application resulted in the highest TSS levels in cucumbers. Similarly, the highest vitamin C content (mg/100g) was recorded with the application of GA_3 100 ppm i.e., 5.27, followed by GA3 50 ppm+ NAA 100 ppm i.e., 5.04, while the lowest ascorbic acid was found in the control i.e., 3.98. It is likely due to GA_3's role in enhancing sugar accumulation, nutrient uptake, and promoting healthy fruit development. These findings are in line with those reported by Manna and Singh (2024).

Table 1: Effect of PGRs on growth parameters of cucumber

Treatments	Vine length (cm)	No of branches (Per plant)	No of nodes (Per plant)	No of leaves (Per plant)
T_1-GA3 (50 ppm)	123.56	5.86	18.78	43.56
T_2-GA3 (100 ppm)	128.89	6.41	20.44	45.78
T_3-NAA (50 ppm)	121.88	5.53	18.33	42.33
T_4-NAA (100 ppm)	125.45	6.08	19.56	42.56
T_5-Ethrel (50 ppm)	119.56	5.45	18.11	40.44
T_6-Ethrel (100 ppm)	121.44	5.64	18.78	41.89
T_7-GA3+NAA (50+100 ppm)	130.44	6.78	21.67	48.67
T_8-GA3+Ethrel (50+100 ppm)	127.80	6.30	19.89	44.55
T_9-Control	116.67	4.75	16.56	38.45
S.Em±	2.12	0.10	0.33	0.70
CD at 5% Level	6.34	0.31	1.00	2.10

Table 2: Effect of PGRs on *Phenological* characterstics

Treatments	Days for first male flower initiation	Days for first female flower initiation	Days to 50% flowering	No of male flower/ plant	No of female flower/plant	Sex ratio
T_1-GA3 (50 ppm)	34.15	38.10	40.85	36.34	15.67	2.31
T_2-GA3 (100 ppm)	32.32	36.20	37.30	35.45	17.66	2.07
T_3-NAA (50 ppm)	36.60	40.05	40.98	35.76	15.24	2.34
T_4-NAA (100 ppm)	38.43	43.25	42.39	33.35	16.45	2.02
T_5-Ethrel (50 ppm)	37.43	43.68	41.74	34.73	19.84	1.75
T_6-Ethrel (100 ppm)	37.05	41.41	41.06	37.38	21.63	1.72
T_7-GA3+NAA (50+100 ppm)	33.10	37.66	39.20	37.55	17.86	2.10
T_8-GA3+Ethrel (50+100 ppm)	35.68	40.35	40.87	38.33	20.55	1.86
T_9-Control	41.04	46.24	49.10	39.33	14.78	2.66
S.Em±	0.51	0.73	0.62	0.56	0.31	0.10
CD at 5% Level	1.54	2.20	1.86	1.68	0.93	0.30

Table 3: Fruit and yield parameters

Treatments	Fruit length (cm)	Number of fruts^{-1}	Fruit diameter (cm)	Fruit weight (cm)	Fruit yield plant-1 (Kg)	Fruit yield plot-1 (Kg)	Yield (qha.-1)
T_1-GA3 (50 ppm)	16.24	17.84	4.38	4.38	2.19	13.14	145.99
T_2-GA3 (100 ppm)	18.38	18.04	4.54	4.54	2.38	14.28	158.66
T_3-NAA (50 ppm)	16.64	16.10	4.06	4.06	2.03	12.18	135.33
T_4-NAA (100 ppm)	17.56	16.90	4.14	4.14	2.12	12.72	141.33
T_5-Ethrel (50 ppm)	16.12	16.07	3.79	3.79	1.89	11.34	125.99
T_6-Ethrel (100 ppm)	16.82	16.30	3.96	3.96	1.94	11.64	129.33
T_7-GA3+NAA (50+100 ppm)	19.55	18.32	4.99	4.99	2.51	15.18	167.33
T_8-GA3+Ethrel (50+100 ppm)	18.26	18.07	4.62	4.62	2.30	13.80	153.33
T_9-Control	14.78	15.77	3.65	3.65	1.82	10.98	121.99
S.Em±	0.39	0.31	0.07	0.07	0.04	0.20	2.50
CD at 5% Level	1.18	0.94	0.21	0.21	0.12	0.59	7.49

Table 4: Quality attributes

Treatments	Total soluble solids (°Brix)	Ascorbic acid (mg 100 g-1)
T_1-GA3 (50 ppm)	3.82	4.56
T_2-GA3 (100 ppm)	4.57	5.27
T_3-NAA (50 ppm)	3.14	4.31
T_4-NAA (100 ppm)	3.96	4.48
T_5-Ethrel (50 ppm)	2.56	4.02
T_6-Ethrel (100 ppm)	2.87	4.13
T_7-GA3+NAA (50+100 ppm)	4.34	5.04
T_8-GA3+Ethrel (50+100 ppm)	3.89	4.83
T_9-Control	2.52	3.98
S.Em±	0.05	0.08
CD at 5% Level	0.16	0.24

Conclusion

The experiment demonstrated that GA_3 50 ppm + NAA 100 ppm was the most effective treatment for improving yield and yield-related traits in cucumber, though further studies are needed for confirmation. The application of plant growth regulators, particularly GA_3 50 ppm + NAA 100 ppm, significantly enhanced growth parameters such as vine length, number of branches, nodes, and leaves per plant. GA_3 100 ppm also had a notable impact on phenological traits like days to first flowering, 50% flowering, and first picking. Additionally, Ethrel 100 ppm was effective in reducing the sex ratio, while the highest sex ratio was observed in the control group. The combined application of GA_3 and NAA significantly increased yield-contributing traits like fruit length, diameter, number of fruits per plant, and overall fruit yield, with the highest yield from GA_3 50 ppm + NAA 100 ppm. The quality attributes, including total soluble solids and ascorbic acid content, were significantly improved by GA_3 100 ppm, followed by the combination of GA_3 50 ppm + NAA 100 ppm, compared to the control.

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