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Effect of Exogenous Plant Growth Regulators on Growth, Yield, and Quality of Parthenocarpic Cucumber/English Cucumber (*Cucumis sativus* L.) under Protected Condition

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study was carried out during the Rabi season 2022-2023 to investigate the effect of different levels of NAA, GA3, and TIBA on the growth, yield, and quality of Pusa Parthenocarpic cucumber – 6 and to estimate the economics. The study was conducted from January to March 2023, the research revealed NAA's significant effect on vine length, earliness parameters, yield, and quality

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attributes. Treatment 8 (NAA@200ppm) emerged as particularly promising, demonstrating superior growth with an average plant height of 290 cm, accelerated development with an average fruit weight of 252.67 g, and a maximum benefit-cost ratio of 2.39.

Keywords: Parthenocarpic cucumber; pusa variety 6; exogenous PGR; BC ratio.

1. INTRODUCTION

Cucumber (*Cucumis sativus* L.) is a widely cultivated plant, belonging to the family Cucurbitaceae and having a chromosome number, 2n =14 [1]. It is an endemic vegetable in India. It is a fruit that is commonly used as a vegetable in cuisines all over the world. Cucumbers are often eaten raw in salads or pickled in vinegar to make a tasty snack. The cucumber has a crunchy texture and a refreshing taste, making it a great addition to any meal. There are several different varieties of cucumbers available, including English cucumbers, Persian cucumbers, and pickling cucumbers. English cucumbers are longer and thinner than other varieties, while Persian cucumbers are shorter and have a sweeter flavor. Pickling cucumbers are smaller and are ideal for making pickles [2]. Cucumbers are a low-calorie food that is high in vitamins and minerals. They are a great source of vitamin C, vitamin K, and potassium. Bursting with antioxidant power, which helps neutralize harmful free radicals that can damage cells [3]. In addition to being a healthy food, cucumbers also have some cosmetic benefits. They are often used in beauty treatments to help soothe and hydrate the skin. Cucumber slices can be placed over the eyes to reduce puffiness and dark circles [4].

Parthenocarpic Cucumber is gaining importance in Urban and Peri-Urban Farming mostly due to its taste, colour and nature. The promising sweet varieties have gained an overwhelming response from the market. Parthenocarpy refers to the ability of plants to produce fruit without fertilisation, resulting in seedless fruits. This characteristic is highly desirable in cucumber cultivation as it enhances fruit quality and market value. Parthenocarpic cucumbers are cucumber varieties that can produce fruit without the need for pollination. These varieties are sometimes referred to as self-pollinating, but technically, they do not require pollination to set fruit. The development of cucumbers without fertilization occurs due to genetic factors or the application of plant hormones [5].

Parthenocarpy in cucumber cultivation offers several advantages. First, it ensures a higher rate of fruit set, as it bypasses the need for pollination and eliminates the dependence on pollinators. This is particularly beneficial in conditions where pollinators are scarce or inefficient. Second, parthenocarpic cucumbers can be harvested earlier compared to pollinated ones. This early harvest allows for an extended harvesting period and increased overall yield. Another benefit of parthenocarpy is the production of seedless cucumbers [6]. These seedless varieties are preferred by consumers as they have a more pleasant texture and taste [7]. Additionally, the absence of seeds eliminates the need for seed removal, making them more convenient. Ninet-five percent of a raw cucumber (with peel) is water, 4% is carbohydrate, 1% is protein, and very little fat is present. A reference serving of 100 grammes (3+1⁄2-ounces) has 65 kilojoules (16 kilocalories) of food energy. Its micronutrient content is minimal; only vitamin K, with 16% of the Daily Value, stands out [8].

Parthenocarpic cucumbers also tend to exhibit greater resilience to environmental factors such as heat, drought, and low light. Their ability to develop fruit without depending on pollination makes them more resistant to adverse conditions, making them suitable for cultivation in challenging climates. However, the occurrence of parthenocarpy is often inconsistent, and external factors such as plant growth regulators can influence its expression.

NAA (naphthaleneacetic acid), GA (gibberellic acid), and TIBA (2,3,5-triiodobenzoic acid) are well-known plant growth regulators commonly used in horticulture and agriculture. NAA is a synthetic auxin that promotes cell elongation and fruit growth. GA stimulates plant growth, including internode elongation and seed germination. Conversely, TIBA is a synthetic auxin transport inhibitor that affects various plant growth processes [9].

By applying different concentrations and combinations of NAA, GA, and TIBA, the study examined their individual effects on plant growth parameters such as plant height, leaf area, and

stem diameter, as well as fruit quality attributes like fruit weight, size, shape, colour, and nutrient content. The findings of this study will contribute to the understanding of how plant growth regulators can influence the growth, yield, and quality of parthenocarpic cucumber plants. This knowledge can help optimize cucumber cultivation techniques, improve crop productivity, and enhance the economic viability of cucumber production under protected conditions.

2. MATERIALS AND METHODS

This experiment was carried out from January to March 2023 in the Horticulture Research Field, Department of Horticulture, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj (U.P). Prayagraj is positioned at an altitude of 78 meters above sea level, located at 25.870 degrees North latitude and 81.150 degrees East longitude. This area experiences a sub-tropical climate, prevailing in the South-Eastern part of Uttar Pradesh. It exhibits both extreme temperatures, with chilly winters and scorching summers. In winter, temperatures can drop as low as 32 degrees Fahrenheit (0 degrees Celsius) in December and January, while summer temperatures can soar up to 115 degrees Fahrenheit (46 degrees Celsius) in May and June. Frost is common in winter, and hot, dry winds prevail during summer. The average annual rainfall is approximately 1013.4 centimeters, with the heaviest rainfall occurring from July to September and occasional showers in winter. The experimental area's soil belongs to the Vegetable Science block of the Horticulture department, characterized as medium lowland with a soil pH of approximately 6.8. Soil characteristics for the experiment were analyzed in the Soil Science department. The experimental site experiences a subtropical climate, with three distinct seasons: winter from November to February, the pre-monsoon or hot season from March to April, and the monsoon period from May to October. Ten treatments were used, including a control (Table 1) and three replications in a completely randomised design with a spacing of 60×30 cm were applied at 2 and 4 true leaf stages under protected conditions, Gynoecious parthenocarpic cucumber (*Cucumis sativus* L.) var. Pusa Parthenocarpic Cucumber-6 was the subject of the experiment. Each treatment group consisted of five randomly chosen plants for the observational recording of metrics related to growth, earliness, yield, quality, economic and quality parameters viz. Total soluble solids (TSS) were determined using a refractometer, while the vitamin C content was assessed through the titration method recommended by Rangana [10]. The readings for Chlorophyll content per leaf were taken using a SPAD-502 meter. The information gathered throughout the inquiry was exposed to Fisher's description of statistical analysis of variance (ANOVA) [11].

Table 1. Various levels of TIBA, GA3 and NAA

Sr. No.	Treatment	Treatment Combination
1	T0	Water
2	T1	TIBA@50ppm
3	T2	TIBA@100ppm
4	T3	TIBA@150ppm
5	T4	GA@500ppm
6	T5	GA@1000ppm
7	T6	GA@1500ppm
8	T7	NAA@100ppm
9	T8	NAA@200ppm
10	T9	NAA@300ppm

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Plant height

Table 2 presents notable variations in vine length, with the most substantial measurement observed 45 days after sowing. Specifically, T8 (NAA@200ppm) exhibited the longest vine length, reaching 292.00 cm, followed by T7 (NAA@100ppm) with a measurement of 130.51 cm. In contrast, the control group (T0) recorded a shorter vine length of 171.00 cm according to the data in Table 2. Naphthalene Acetic Acid (NAA) plays a pivotal role in the physiological processes occurring throughout the growth period. It enhances cell division and elongation while also elevating the permeability of the cell wall. This heightened permeability facilitates the entry of a greater quantity of water and dissolved materials into the cell, ultimately contributing to increased cell size and overall growth [12].

3.1.2 Number of primary branches

Table 2 presents notable variations in the mean of the number of branches, with the most substantial measurement observed 45 days after sowing. Specifically, T8 (NAA@200ppm) exhibited the highest number reaching 4.60,

followed by T9 (NAA@300ppm) with a number of 3.80. In contrast, the control group (T0) has a minimum number of 3.40 according to the data in Table 2. There exists a direct correlation between the main vine and the formation of primary branches in plants. This means that an increase in the length of the main vine leads to a corresponding increase in the number of primary branches, and vice versa. The observed significance in results could be attributed to the reversible impact on plant mitosis caused by the application of NAA. This, in turn, results in a greater number of primary branches on the main branches of cucumber. Hence, a longer vine length contributes to a higher count of primary branches. Similar findings were also reported by Dalai et al. [13].

3.1.3 Number of nodes

At the 45-day mark post-transplantation, the highest node count was documented in T8 (NAA@200ppm), reaching 11.27, followed by T9 (NAA@300ppm) reaching 11.20. In contrast, the minimum number of nodes was observed in T0 (control), registering at 9.73. The significant rise in the node count could be attributed to the potential stimulation of meristematic tissues by auxin, hastening increased cell division and enlargement in actively growing sections. These observations align with the research outcomes reported by Viradia et al. [14] and El-Soad et al. [15].

3.2 Earliness Parameters

3.2.1 Days to first flowering

The data regarding the days taken for the first appearance of female flowers reveals a statistically significant outcome. The shortest duration for the emergence of the first female flowering was observed in T8 (NAA@200ppm) at 33.80 days (mean), followed by T1 (TIBA@50ppm) at 34.60 days (mean), while the longest duration was noted in T0 (control) at 43.34 days (mean), as presented in Table 2. Cucumber flowers are typically characterized by their small size and yellow colour, featuring 3-6 petals per blossom. The development of cucumber flowers is significantly influenced by auxin. A detailed study has been reported by Sharif et al. [16].

3.2.2 Days to first fruit setting

The analysis of data revealed that the maximum number of days taken for the first fruit setting was observed in the control group (T0) at 49.62 days (mean), whereas the minimum duration was recorded in treatment T8 (NAA@200ppm) at 40.08 days (mean). Following closely was the treatment T1 (TIBA@50ppm) with a time frame of 40.88 days (mean) for the first fruit setting. Auxin has been widely utilised to achieve successful fruit setting without fertilization. In a study conducted by Qian et al. [17], the advantages of externally applying auxin for the induction of parthenocarpic fruit in cucumbers were demonstrated. Specifically, Naphthaleneacetic acid (NAA) at a concentration of 100 mg/L was sprayed on unpollinated cucumber ovaries. The cucumbers treated with NAA exhibited successful fruit setting, in contrast to untreated ovaries, which did not undergo successful fruit development.

3.2.3 Days to first fruit picking

The analysis of data revealed that the maximum number of days taken for the first fruit setting was observed in the control group (T0) at 58.03 days (mean), whereas the minimum duration was recorded in treatment T8 (NAA@200ppm) at 48.5 days (mean). Following closely was the treatment T1 (TIBA@50ppm) with a time frame of 49.3 days (mean) for the first fruit picking. As Auxin is found in higher concentration in the parthenocarpic line of cucumber the NAA treatment reduced the fruit abortion and increased the photosynthetic effect to induce the carbohydrates accumulation in fruit to be ready for harvest earlier. The same case study has been reported by Sharif et al. [16].

3.3 Yield Parameters

3.3.1 Number of female flowers per plant

The data analysis indicated that the highest number of female flowers per plant was observed in treatment T8 (NAA@200ppm), reaching 16.41. Following closely was T5 (GA@1000ppm) with a count of 16.24. In contrast, the minimum number of female flowers per plant was found in treatment T0 (control) at 13.60. This phenomenon may be attributed to the elevated levels of exogenous auxin, specifically Naphthaleneacetic acid (NAA). The higher concentration of NAA is likely to initiate and sustain additional floral meristems, consequently leading to an augmented number of female flowers. Additionally, auxin plays a crucial role in the growth and differentiation of carpels, fostering the development of more female

flowers. A similar study has been reported by Sharif et al. [16].

3.3.2 Average fruit weight (gm)

The data analysis indicated that the maximum average fruit weight per plant was observed in treatment T8 (NAA@200ppm), reaching 252.67 grams Following closely was T9 (NAA@300ppm) with 230.67 grams. In contrast, the minimum number of female flowers per plant was found in treatment T0 (control) at 130.67 grams. Naphthaleneacetic acid (NAA) is a synthetic auxin with a physiological function similar to that of Indole-3-acetic acid (NAA). Due to its lower cost and increased stability, NAA is deemed more suitable for application in crop production. Following the fruit set, the majority of assimilates produced through photosynthesis are allocated to fruit growth, with a portion reserved for essential physiological activities such as growth and respiration. Auxins play a role in enhancing the photosynthetic capacity of leaves and regulating the loading, transport, and distribution of photoassimilates. This, in turn, improves the seed setting rate and contributes to an increase in crop weight. Parallel findings were reported by Chen et al. in Giant Pumpkin [18].

3.3.3 Number of fruits per plant

The analysis of the data revealed that the maximum number of fruits per plant was recorded in treatment T8 (NAA@200ppm), reaching 9.87. Following closely was T7 (NAA@100ppm) with a 9.27 count of fruits per plant. In contrast, the minimum number of fruits per plant was found in treatment T0 (control) at 8.27. NAA plays a regulatory role in increasing the number of female flowers and decreasing the male-to-female sex ratio. The presence of female flowers at lower nodes on the main vine contributes to a potential reduction in fruit abortion. Consequently, this led to a proportional increase in the number of fruits per plant. Additionally, the fresh weight per fruit tends to be at its highest under these conditions. A similar study was found by Akter and Rahman, in Bitter Gourd [19]. The study found that treatment with IAA, which had the lowest male to female sex ratio, resulted in the highest number of female flowers, fruits, fresh weight of fruits, and yield per plant. This suggests that a lower male to female sex ratio may be beneficial for cucumber production.

3.3.4 Fruit yield per plot (kg)

The analysis of the data revealed that the maximum number of fruits per plot was recorded in treatment T8 (NAA@200ppm), reaching 10.93 kg. Following closely was T6 (GA@1500ppm) with 9.55 kg of fruits per plant. In contrast, the minimum number of fruits per plant was found in treatment T0 (control) at 6.84 kg. NAA, along with various other plant growth regulators, are recognised for inducing physiological changes in plants, primarily impacting flowering behaviour, sex ratio, increased fruit set, and the enlargement and development of fruits. Additionally, they play a role in influencing the source-sink relationship in plants. The application of growth regulators brings about specific alterations in metabolic processes during fruit and seed development. This, in turn, leads to a greater accumulation of food reserves, ultimately contributing to a higher yield. A similar study was found by Akter and Rahman, in Bitter Gourd [19], treatment with IAA had the highest values from all the metrics taken. This suggests that a lower male to female sex ratio may be beneficial for cucumber production which increase the production per plant and eventually increase the yield per plot.

3.3.5 Fruit length (cm)

The analysis of the data revealed that the maximum fruit length was recorded in treatment T8 (NAA@200ppm) at 17.68 cm, closely followed by T1 (TIBA@50ppm) with a length of 17.74 cm. In contrast, the minimum fruit length was found in treatment T0 (control) at 15.15 cm. Fruit length is a significant agronomic trait in cucumber breeding. The metabolic effect of NAA associated with this trait results in the acceleration of cell enlargement and the inhibition of cell division. As a consequence, this metabolic influence contributes to the attainment of the highest possible fruit length. A similar study was reported by Dahal et al. in chilli [20]. Researchers in Mandhana, India, conducted a field study between February and May 2022 to explore the impact of varying concentrations of naphthalene acetic acid (NAA) on the growth and yield of chili plants. The study aimed to identify how different NAA levels affect various growth parameters in chili peppers.

3.3.6 Fruit diameter (cm)

The data analysis indicated that the maximum fruit diameter was recorded in treatment T8

Table 2. Effect of PGRs on growth, earliness, and yield parameters of Parthenocarpic Cucumber

Treatment	Plant Height (cm)	No of Primary Branches	No of Nodes	Days to first flowering	Days to fruit setting	Days to first fruit picking	No. of female flowers per plant	Avg. fruit weight (g)	No. of fruits per plant	Fruit yield per plot (kg)	Fruit length (cm)	Fruit diameter (cm)
T0	171	3.40	9.73	43.34	49.62	58.03	13.60	130.67	8.20	6.84	15.15	3.59
T1	193.33	3.80	10.33	34.60	40.88	49.30	13.69	149.67	8.33	7.76	17.74	4.06
T2	218.33	3.73	9.93	42.67	48.95	57.36	14.92	187.67	9.00	9.50	17.24	3.95
T3	224.33	3.80	12.07	38.34	44.62	53.04	15.25	216.33	9.20	8.48	16.93	4.36
T4	173.33	3.73	10.13	40.08	46.36	54.78	13.77	157.00	8.27	8.10	16.18	4.01
T5	213.67	3.60	10.80	39.98	46.26	54.68	16.24	177.00	9.80	9.29	16.57	3.79
T6	195.00	3.60	10.93	35.08	41.36	49.78	14.26	175.33	8.60	9.55	16.91	3.83
T7	253.33	3.67	10.40	38.19	44.47	52.88	15.42	177.00	9.27	8.45	16.79	4.36
T8	292.00	4.60	11.27	33.80	40.08	48.50	16.41	252.67	9.87	10.93	17.68	4.56
T9	240.00	3.80	11.20	37.67	43.95	52.37	14.11	230.67	8.60	9.07	16.42	3.42
F Test	S	S	S	S	S	S	S	S	S	S	S	S
SE(d)±	14.39	0.35	0.59	1.45	1.45	1.54	0.42	16.45	0.21	0.92	0.69	0.42
CD 5%	3.02	0.73	1.24	3.04	3.05	3.58	0.89	3.45	0.45	1.93	1.45	0.89
CV	8.10	11.25	6.76	4.62	3.97	3.34	3.51	10.87	2.94	12.82	5.04	12.94

Table 3. Effect of PGRs on Qualitative Parameters of Parthenocarpic Cucumber

Treatment	Chlorophyll Content (SPAD Value)	TSS (ºBrix)	Vitamin C (mg/100g)	Juice %	Dry Matter Content
T0	22.90	4.52	4.54	75.97	4.31
T1	33.46	4.73	4.71	78.21	5.57
T2	33.57	5.23	4.65	82.79	6.18
T3	30.87	5.91	5.64	89.30	5.44
T4	26.07	5.47	5.69	89.08	5.81
T5	29.70	5.87	5.16	80.22	5.88
T6	26.07	5.33	5.30	82.39	5.54
T7	28.87	5.33	5.08	84.16	5.26
T8	36.83	6.03	5.70	91.50	6.83
T9	25.73	5.28	5.16	84.28	5.11
F Test	S	S	S	S	S
SE(d)±	0.31	0.38	0.31	3.10	0.71
CD 5%	0.65	0.81	0.65	6.50	1.50
CV	1.29	8.76	7.31	4.52	15.63

Table 4. Cost of cultivation of Parthenocarpic Cucumber under protected condition

Sr. No.	Particulars	Unit	Rate/Unit	Quantity	Cost (Rs/ha)
1	Land Preparations	Man-days	500	6	3,000
2	Mulching	KG	150	100	15,000
3	Vermicompost	Ton	2000	10	20,000
4	Seeds	KG	2	10,000	20,000
5	Sowing	Man-days	500	7	3,500
6	Irrigation (Electricity)	KWH	3	1,200	3,600
7	Training Wire (steel)	KG	120	20	2,400
8	Training Wire (nylon)	KG	180	5	900
9	Harvesting	Man-days	500	25	12,500
10	Land (inc. poly house and irrigation system)	Months	10,000	2	20,000
11	Misc. Labour	Man-days	500	4	2,000
	Total				**1,02,900**

Table 5. Economies of different treatments done on Parthenocarpic Cucumber for this study

Treatments	Fruit Yield (t/ha)	Cultivation Cost (INR)	Gross Revenue (INR)	Net Returns (INR)	Benefit:Cost Ratio
T0	3.42	1,02,900	1,53,900	51,000	1.50
T1	3.88	1,02,900	1,74,600	71,700	1.70
T2	4.75	1,02,900	2,13,750	1,10,850	2.08
T3	4.24	1,02,900	1,90,800	87,900	1.85
T4	4.05	1,02,900	1,82,250	79,350	1.77
T5	4.64	1,02,900	2,08,800	1,05,900	2.03
T6	4.77	1,02,900	2,14,650	1,11,750	2.09
T7	4.23	1,02,900	1,90,350	87,450	1.85
T8	5.47	1,02,900	2,46,150	1,43,250	2.39
T9	4.54	1,02,900	2,04,300	1,01,400	1.99

(NAA@200ppm) at 4.56 cm, followed by T7 (NAA@100ppm) with a diameter of 4.36 cm. In contrast, the minimum fruit diameter was observed in treatment T0 (control) at 3.59 cm. Similar results were observed by Anbarasi et al. [21]. The observed increase in diameter can be attributed to both, an increase in the number of cells and the elongation of cells, which are characteristic actions of any group of auxins.

3.4 Quality Parameters

3.4.1 Chlorophyll content (SPAD value)

The SPAD-502 meter, a portable device, is extensively utilized for swiftly and accurately gauging leaf chlorophyll levels without causing damage. Its application spans various research and agricultural contexts and encompasses diverse plant species. Readings from the SPAD-502 meter yield relative values directly correlating to the chlorophyll content within the leaf. While taking the readings for Chlorophyll content per leaf using a SPAD-502 meter, the following observations were recorded. After 15 days, the maximum reading was recorded in treatment T8 (NAA@200ppm) at 40.90, followed by T3 (TIBA@150ppm) at 38.63. The minimum recording was recorded in treatment T0 (control) at 34.77. After 30 days, the maximum reading was recorded in treatment T8 (NAA@200ppm) at 38.87, followed by T1 (TIBA@50ppm) at 35.78. The minimum recording was recorded in treatment T0 (control) at 29.15. After 45 days, the maximum reading was recorded in treatment T8 (NAA@200ppm) at 36.83, followed by T2 (TIBA@100ppm) at 33.57. The minimum recording was recorded in treatment T0 (control) at 22.90. Leaves play a crucial role in various plant activities, including photosynthesis, respiration, and transpiration. The exogenous application of Naphthaleneacetic acid (NAA) effectively enhances leaf photosynthetic performance, potentially through the increase in leaf area and chlorophyll content. This improvement may also be associated with enhancements in both stomatal and non-stomatal restrictions, along with the reinforcement of photosynthetic system II, as compared to other treatments. Parallel findings were reported by Uddin et al. in Bishop's weed [22].

3.4.2 TSS (°Brix), vitamin C, juice percentage and dry matter content

Various readings were taken while determining the qualitative parameters. TSS (°Brix) was

maximum in treatment T8 (NAA@200ppm) at 6.03 ^{o}Brix, followed closely by treatment T3 (TIBA@150ppm) at 5.91 ^{o}Brix, and the lowest in treatment T0 (control) at 4.52 ^{o}Brix.

Vitamin C content (mg/100g) was recorded highest in the treatment T8 (NAA@200ppm) at 5.70 mg/100g, followed very closely by the treatment T4 (GA@500ppm) at 5.69 mg/100g, and the lowest in the treatment T0 (control) at 4.54 mg/100g. Ascorbic acid, being a highly unstable vitamin, is susceptible to changes in its content due to exposure to heat, oxygen, and light. Additionally, the manner of washing, whether in still or turbulent water, can induce mechanical stress, leading to a reduction in the nutrient concentration (Dewhirst et al. [23]). However, the study was done under a protected environment, hence the exposure to external environmental factors was very minimised due to which the Vitamin C content might be unaffected.

Juice percentage was recorded highest in treatment T8 (NAA@200ppm) at 91.50%, followed very closely by treatment T3 (TIBA@150ppm) at 89.30%, and the lowest in the treatment T0 (control) at 75.97%.

Dry matter content (in grams) was recorded maximum in the treatment T8 (NAA@200ppm) at 6.83 grams, followed closely by the treatment T (TIBA@100ppm) at 6.18 grams, and the lowest in the treatment T0 (control) at 4.31 grams.

Auxins play an important role in the metabolic rates and increase the photosynthetic activities in the plants which led to the higher nutrient contents, so these parameters might have been affected by it. Similar results were found by Vidyullatha et al. [24] and Sravika et al. [25].

3.5 Economics of Various Treatments

The highest gross returns were observed in Treatment 8 (NAA@200ppm) at Rs. 2,46,150, followed by T6 (GA@1500ppm) at Rs. 2,14,650. Conversely, the lowest returns, amounting to Rs. 1,53,900, were noted in T0 (control).

In terms of net returns, Treatment 8 (NAA@200ppm) demonstrated the highest figure at Rs. 1,43,250, followed by T6 (GA@1500ppm) at Rs. 1,11,750. The lowest net returns, totalling Rs. 51,000, were registered in T0 (control).

Regarding the Benefit-Cost (BC) ratio, Treatment 8 (NAA@200ppm) exhibited the highest ratio at 2.39, followed by T6 (GA@1500ppm) at 2.09. The lowest BC ratio, recorded at 1.50, was associated with T0 (control). All these data are shown in the table 5.

4. CONCLUSION

This study concluded that NAA (200 ppm) performed best in terms of growth (vine length at 292 cm, chlorophyll content at 36.83), yield (5.47 t/ha), and quality (TSS value at 6.03 ^{o}Brix, dry matter content at 6.83 grams). The highest BC ratio was at 2.39 in the treatment T8 (NAA @ 200 ppm).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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