**Effect of Gibberellic Acid and Naphthalene Acetic Acid on Growth, Yield and Quality of strawberry (*Fragaria× ananassa* Duch) cv. Winter Dawn under controlled condition**

**ABSTRACT**

The experiment was conducted using the Randomized Block Design (RBD) with 8 treatments, viz., T1: GA₃ 50 ppm, T2: GA₃ 100 ppm, T3: NAA 20 ppm, T4: NAA 40 ppm, T5: GA₃ 50 ppm + NAA 20 ppm, T6: GA₃ 50 ppm + NAA 40 ppm, T7: GA₃ 100 ppm + NAA 20 ppm, and T8: GA₃ 100 ppm + NAA 40 ppm, with three replications. Maximum plant height (23.10 cm), number of leaves per plant (22.27), number of flowers per plant (19.43), number of runners per plant (9.65), and plant spread in the east–west (23.09 cm) and north–south (23.99 cm) directions were recorded under treatment T8 at 90 days after transplanting (DAT). Similarly, maximum fruit length (53.54 mm), fruit weight (14 g), number of fruits per plant (21.78), yield per plant (304.70 g), and yield per hectare (253.54 q/ha) were also obtained under T8. The highest TSS (9.60°Brix) and ascorbic acid content (60.26 mg/100 g) were observed under T8, whereas the highest total sugar content (8.54%) was recorded under T6. The findings revealed that the highest cost of cultivation (₹17,54,741/ha), net profit (₹53,44,379/ha), and benefit–cost ratio (3.0) were obtained under T8.

**KEY WORD :-**GA3 , NAA , Growth, Cultivation ,Flowers ,Yield ,Cost Benefit-ratio, Net profit ,Strawberry ,Winter Dawn.

**INTRODUCTION**

 Strawberry is an important major fruit crop that is self-pollinated and highly perishable in nature. It originated through hybridization between two wild species, Fragaria virginiana and Fragaria chiloensis. Strawberry belongs to the family Rosaceae. The edible part of the strawberry is the thalamus. It is a bisexual plant with a fibrous and shallow root system. The flower structure consists of five sepals, five petals, 20–30 stamens, and four types of pistils, with white-colored flowers. The red coloration of the berries is attributed to the presence of anthocyanin pigments. Strawberry is adaptable to a wide range of climatic and soil conditions, but sandy loam soils with a pH of 5.0 to 6.5 are considered ideal. The optimum temperature for strawberry growth is 22–23 °C during the day and 7–13 °C at night. It is categorized as an accessory fruit and a false berry, as it develops without fertilization. The inflorescence of strawberry is a thyrse, consisting of a monopodial primary axis and sympodial lateral branches. It is a low-growing cash crop, cultivated worldwide due to its high net profit potential in a short period and small area. Strawberries are rich in vitamins, minerals, and dietary fibers, and possess medicinal properties that contribute to daily nutritional requirements. They contain high levels of antioxidants and anti-cancerous compounds such as ellagic acid and flavonoids (Roussos et al., 2009). According to the U.S.D.A. (2019), 100 grams of raw strawberries contain: Total sugar: 5.3 g, Dietary fiber: 1.8 g, Protein: 0.7 g, Vitamin C: 56 mg, Manganese: 0.28 mg, Fructose: 2.84 g, Glucose: 2.39 g, Calcium: 12 mg, Phosphorus: 20 mg, Magnesium: 0.28 mg, Potassium: 89 mg, Sodium: 10 mg, Vitamin A: 1 µg, Total lipids: 0.22 g, Riboflavin: 0.016 mg, Sucrose: 0.11 g

As per NHB reports, Mahabaleshwar (Maharashtra) is regarded as the Strawberry Capital of India, while Haryana ranks first in strawberry production. During 2022–23, the area under strawberry cultivation in India was 2,000 hectares, with a production of 19,000 metric tons (MT). In 2024–25, maximum production was 17,000 MT from the same area, contributing nearly 30% of the total world production. The United States remains the largest producer of strawberries globally. According to the World Population Review, China has led in strawberry production since 1994. In 2023, the United States ranked second, producing 1,055,963 tons. Egypt narrowly surpassed Mexico for third place, producing 597,029 tons compared to Mexico's 557,514 tons. Turkey followed with 546,525 tons, while Spain, Brazil, Russia, Poland, and Morocco also featured among the top producers with yields ranging from 272,550 to 166,955 tons. Strawberries are widely used in the preparation of value-added products such as pickles, chutneys, kimchi, desserts, cakes, juices, jellies, ice creams, and sorbets. Various plant growth regulators like GA₃ and NAA significantly influence the growth stages, yield, and quality attributes of strawberry plants. Foliar application of these PGRs has shown positive effects on growth, yield, and quality parameters (Vishal et al., 2016). GA₃ application enhances vegetative growth parameters such as plant height, number of leaves per plant, plant spread, runner production, and ascorbic acid content, while NAA treatment results in the highest number of flowers per plant (Plaei et al., 2016). The combined use of GA₃ and NAA further improves overall plant growth, flowering, fruit set percentage, fruit size, yield, and fruit quality (Bhople et al., 2019).

**MATERIAL AND METHODS: -**

The field study titled “Effect of Gibberellic Acid and Naphthalene Acetic Acid on Growth, Yield, and Quality of Strawberry (Fragaria × ananassa Duch.) cv. Winter Dawn under Controlled Conditions” was conducted at the Horticulture Research Farm of Rama University, Kanpur (U.P.). All necessary facilities to successfully carry out the experiment were available in the Department of Horticulture, Rama University, Kanpur. The experimental site is geographically situated between 25.25° and 26.58° North latitude and 79.32° to 80.34° East longitude, at an elevation of 125.9 meters above mean sea level. The crop under investigation, strawberry cv. Winter Dawn, was grown using a Randomized Block Design (RBD) with three replications and eight treatments, as follows: T₁: GA₃ 50 ppm, T₂: GA₃ 100 ppm, T₃: NAA 20 ppm, T₄: NAA 40 ppm, T₅: GA₃ 50 ppm + NAA 20 ppm, T₆: GA₃ 50 ppm + NAA 40 ppm, T₇: GA₃ 100 ppm + NAA 20 ppm, T₈: GA₃ 100 ppm + NAA 40 ppm. Each plot measured 1.2 m² with a plant spacing of 40 × 30 cm, accommodating 10 plants per plot. Foliar applications of GA₃ and NAA, both individually and in combination, were applied at 30, 60, and 90 days after transplanting (DAT). Observations on various growth, yield, and quality parameters were recorded at 30, 60, and 90 DAT. These parameters included: Growth attributes: Plant height (cm), number of leaves per plant, number of runners per plant, number of flowers per plant, and plant spread (cm), Yield attributes: Fruit length (mm), fruit weight (g), number of fruits per plant, yield per plant (g), and yield per hectare (q/ha), Quality attributes: Total soluble solids (TSS, °Brix), total sugars (%), and ascorbic acid content (mg/100g), Economic parameters: Cost of cultivation (Rs/ha), net profit (Rs/ha), and benefit-cost (B:C) ratio. For data collection, five healthy representative plants were randomly selected from each treatment. Plant height and plant spread were measured using a meter scale. Fruit length was measured with vernier calipers, and fruit weight was determined using a digital weighing machine. TSS was measured using a hand refractometer. Total sugar content was estimated using the Lane and Eynon method as described by AOAC (1965). Ascorbic acid content was determined using the 2,6-dichlorophenol-indophenol dye titration method. The statistical analysis of the recorded data was carried out as per the methodology described by Panse and Sukhatme (1995).

**Results and discussion**

The results of the present study titled “Effect of Gibberellic Acid and Naphthalene Acetic Acid on Growth, Yield, and Quality of Strawberry (Fragaria × ananassa Duch.) cv. Winter Dawn under Controlled Conditions” are summarized and discussed in Tables 1, 2, and 3. The study aimed to evaluate the effectiveness of Gibberellic Acid (GA₃) and Naphthalene Acetic Acid (NAA) on the growth, yield, and quality attributes of strawberry under controlled environmental conditions.

**Growth Parameters**

With respect to growth parameters such as plant height (cm), number of leaves per plant, number of flowers per plant, number of runners per plant, and plant spread (cm), the maximum values were recorded under treatment T₈ (GA₃ 100 ppm + NAA 40 ppm) through foliar application. These findings suggest that the combined application of GA₃ and NAA at higher concentrations significantly enhanced vegetative growth and floral development in strawberry plants. The data related to these growth parameters are presented in Table 1.

**Table (1). Effect of Gibberellic Acid and Naphthalene Acetic Acid on and NAA on Growth parameter of strawberry (*Fragaria× ananassa* Duch) cv. Winter Dawn under controlled condition**.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Plant height (cm)** | **Number of leaves** | **No. of Flowers per plant** | **Runners per plant** | **Plant spread (cm)** |
| **E-W** | **N-S** | **E-W** | **N-S** | **E-W** | **N-S** |
| **Treatment** | **30DAT** | **60DAT** | **90DAT** | **30DAT** | **60DAT** | **90DAP** | **30DAT** | **60DAT** | **90DAT** |
| **T1** | 6.86 | 13.56 | 18.33 | 6.09 | 11.04 | 16.30 | 17.03 | 4.44 | 9.97 | 10.42 | 14.7 | 15.16 | 20.19 | 20.69 |
| **T2** | 7.90 | 15.56 | 20.36 | 7.81 | 12.55 | 19.68 | 17.83 | 6 | 10.94 | 11.09 | 17.35 | 17.72 | 21.18 | 22.43 |
| **T3** | 5.60 | 9.60 | 15.10 | 3.43 | 7.13 | 10.83 | 15.19 | 3.64 | 8.73 | 8.80 | 12.38 | 12.93 | 15.39 | 16.06 |
| **T4** | 6.80 | 11.80 | 15.77 | 4.90 | 8.41 | 11.66 | 15.88 | 3.43 | 9.20 | 9.81 | 15.20 | 15.86 | 19.30 | 19.67 |
| **T5** | 7.36 | 13.60 | 16.40 | 5.66 | 11.27 | 14.07 | 16.37 | 5.34 | 10.05 | 10.28 | 16.34 | 16.47 | 20.32 | 20.47 |
| **T6** | 8.00 | 14.03 | 17.20 | 6.85 | 12.03 | 16.23 | 16.44 | 6.66 | 10.35 | 10.95 | 16.72 | 17.97 | 20.56 | 20.83 |
| **T7** | 8.26 | 14.63 | 18.15 | 7.92 | 13.70 | 20.09 | 18.13 | 7.65 | 11.19 | 11.22 | 17.95 | 18.62 | 21.29 | 21.95 |
| **T8** | 9.53 | 16.13 | 23.10 | 8.40 | 15.42 | 22.27 | 19.43 | 9.65 | 12.03 | 12.23 | 19.05 | 19.17 | 23.09 | 23.99 |
| **CD** | **0.54** | **0.73** | **1.00** | **0.73** | **0.97** | **1.15** | **0.88** | **0.7** | **1.14** | **1.16** | **1.23** | **1.33** | **1.38** | **1.54** |
| **SE. m** | **0.17** | **0.23** | **0.32** | **0.23** | **0.31** | **0.37** | **0.28** | **0.2** | **0.37** | **0.38** | **0.40** | **0.43** | **0.45** | **0.50** |

The results of the current study titled “Effect of Gibberellic Acid and Naphthalene Acetic Acid on Growth, Yield, and Quality of Strawberry (Fragaria × ananassa Duch.) cv. Winter Dawn under Controlled Conditions” are discussed below and summarized in Tables 1, 2, and 3. The experiment was conducted to evaluate the efficacy of GA₃ and NAA on various growth, yield, quality, and economic parameters of strawberry.

**Growth Parameters**

**Plant Height:**

Maximum plant height at 30, 60, and 90 days after transplanting (DAT) 9.53 cm, 16.13 cm, and 23.10 cm, respectively was recorded under T₈ (GA₃ 100 ppm + NAA 40 ppm). The minimum height 5.60 cm, 9.60 cm, and 15.10 cm was observed under T₃ (NAA 20 ppm). This increase in plant height may be attributed to the positive effect of plant growth regulators (PGRs). These findings are consistent with the results reported by Maya Lamba et al. (2024).

**Number of Leaves per Plant:**

Maximum number of leaves per plant at 30, 60, and 90 DAT 8.40, 15.42, and 22.27, respectively was recorded under T₈, whereas the minimum 3.43, 7.13, and 10.83 was recorded under T₃. These results align with those reported by Kumar et al. (2012a) and Vishal et al. (2023). The increase in leaf number may be due to enhanced epidermal cell division promoted by the PGRs.

**Number of Flowers per Plant:**

Maximum number of flowers per plant (19.43) was observed under T₈, while the minimum (15.19) was recorded under T₃. These results corroborate the findings of Kaveri and Mishra (2023) and Bhople et al. (2019), who reported that the combined application of GA₃ and NAA positively influences flower development due to their complementary hormonal effects.

**Number of Runners per Plant:**

The highest number of runners (9.65) was recorded under T₈, and the lowest (3.43) under T₄. These results are in accordance with the findings of Bhople et al. (2019).

**Plant Spread:**

Maximum plant spread in the east–west direction at 30, 60, and 90 DAT 12.03 cm, 19.05 cm, and 23.09 cm, respectively and in the north–south direction 12.23 cm, 19.17 cm, and 23.99 cm was observed under T₈. The minimum plant spread was recorded under T₃ (E–W: 8.73 cm, 12.38 cm, and 15.39 cm; N–S: 8.80 cm, 12.93 cm, and 16.06 cm). These findings support the work of Vishal et al. (2023) and Maya Lamba et al. (2024). The enhanced spread under T₈ may be attributed to synergistic action of GA₃ and NAA at optimal concentrations.

**Yield Parameters**

Data related to yield attributes such as fruit length, fruit weight, number of fruits per plant, yield per plant, and yield per hectare are presented in Table 2.

 **Fruit Length:** Maximum fruit length (53.54 mm) was recorded under T₈, while minimum (21.50 mm) was observed under T₃. These findings align with those of Vishal et al. (2023).

**Fruit Weight:** Maximum average fruit weight (14.00 g) was recorded under T₈, while the minimum (9.80 g) was observed under T₃, corroborating the results of Singh et al. (2022) and Bhople et al. (2019).

**Number of Fruits per Plant:** The highest number (21.78) was found in T₈, whereas the lowest (15.11) was recorded under T₄, consistent with findings of Kharjana et al. (2022) and Kaveri & Mishra (2023).

**Yield per Plant:** Maximum yield per plant (304.70 g) was recorded under T₈, while the minimum (156.01 g) was recorded under T₃. The higher yield is attributed to increased fruit set and size. These results are in agreement with Kriti et al. (2016) and Bhople et al. (2019).

**Yield per Hectare:** Highest yield (253.54 q/ha) was observed under T₈, whereas the lowest (129.33 q/ha) was recorded under T₃. These findings are in line with those of Singh et al. (2022) and Kriti et al. (2016).

**Quality Parameters**

The data for Total Soluble Solids (TSS), Total Sugars, and Ascorbic Acid content are presented in Table 2.

**TSS (°Brix):** Maximum TSS (9.60°B) was recorded under T₈, while the minimum (6.37°B) was found under T₃. These results support the findings of Rathod et al. (2021) and Kumar et al. (2012a).

**Total Sugars:** The highest total sugar content (8.54%) was recorded under T₆, while the lowest (5.13%) was observed under T₂, in agreement with Rathod et al. (2021).

**Ascorbic Acid:** Maximum ascorbic acid content (60.26 mg/100 g) was recorded under T₈, whereas the minimum (53.54 mg/100 g) was found under T₃, corroborating the results of Vishal et al. (2023) and Kriti et al. (2016).

**Economic Parameters**

Economic data such as cost of cultivation, net profit, and benefit-cost (B:C) ratio are summarized in Table 3. The highest cost of cultivation (₹17,54,741/ha), net profit (₹53,44,379/ha), and B:C ratio (1:3.0) were recorded under T₈. The lowest economic return was recorded under T₃, with a cost of cultivation of ₹17,52,474/ha, net profit of ₹18,68,766/ha, and B:C ratio of 1:1.0. These findings are in close agreement with those reported by Singh et al. (2022) and Rathod et al. (2024).

**Table (2):- Effect of Gibberellic Acid and Naphthalene Acetic Acid on and NAA on yield, quality and economic parameter of strawberry (*Fragaria×***

 ***ananassa* Duch) cv. Winter Dawn under controlled condition**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatment details**  | **YIELD PARAMETER** | **QUALITY PARAMETER** | **ECONOMIC PARAMETERS** |
| **Fruit Length (mm)** | **Fruit weight****(gm)** | **No. of fruit per plant** | **Yield per plant (gm)** | **Yield per plant (q/ha)** | **Total sugar solids****(°B)** | **Total sugar content (%)** | **Ascorbic acid (mg/100g)** | **Total cost of cultivation (Rs/ha )** | **Net profit (Rs/ha )** | **B:C ratio** |
| **T1** | 51.08 | 11.26 | 16.43 | 184.86 | 154.10 | 7.50 | 5.25 | 54.41 | 17,53,436.5 | 25,61,363.5 | 1:1.4 |
| **T2** | 51.61 | 12.4 | 18.61 | 230.39 | 191.06 | 8.26 | 5.13 | 56.39 | 17,54,513.0 | 35,95,167 | 1:2.0 |
| **T3** | 21.50 | 9.80 | 15.94 | 156.01 | 129.33 | 6.37 | 6.32 | 53.54 | 17,52,474.0 | 18,68,766 | 1:1 |
| **T4** | 22.38 | 10.86 | 15.11 | 164.02 | 136.26 | 6.51 | 8.36 | 55.60 | 17,52,588.0 | 20,62,692 | 1:1.2 |
| **T5** | 51.51 | 11.8 | 16.44 | 194.08 | 161.57 | 7.70 | 5.80 | 56.48 | 17,53,550.5 | 27,70,409.5 | 1:1.5 |
| **T6** | 52.43 | 12 | 19.11 | 229.13 | 190.48 | 7.43 | 8.54 | 59.12 | 17,53,664.5 | 35,79,775.5 | 1:2 |
| **T7** | 52.34 | 13.2 | 20.44 | 269.15 | 223.20 | 8.30 | 5.75 | 57.97 | 17,54,627.0 | 44,94,973 | 1:2.5 |
| **T8** | 53.54 | 14 | 21.78 | 304.70 | 253.54 | 9.60 | 6.66 | 60.26 | 17,54,741.0 | 53,44,379 | 1:3.0 |
| **C.D** | 1.38 | 0.5 | 1.19 | 0.73 | 1.58 | 0.60 | 0.47 | 0.91 | **\_\_\_\_** | **\_\_\_\_** | **\_\_\_\_** |
| **SE. m** | 0.45 | 0.17 | 0.38 | 0.24 | 0.51 | 0.28 | 0.15 | 0.29 | **\_\_\_\_\_** | **\_\_\_\_** | **\_\_\_\_** |

**CONCLUSION**

Based on the findings of the present study, it can be concluded that the treatment T₈ (GA₃ 100 ppm + NAA 40 ppm) exhibited the most significant positive effects on strawberry growth, yield, quality, and economic performance under controlled conditions. This treatment was found to be the most effective in enhancing growth parameters such as plant height, number of leaves, number of flowers per plant, number of runners, and plant spread (cm). It also outperformed all other treatments in terms of yield attributes and economic returns. With respect to quality parameters, T₈ recorded the highest total soluble solids (TSS, °Brix) and ascorbic acid content (mg/100g). However, the maximum total sugar content (%) was observed under T₆ (GA₃ 50 ppm + NAA 40 ppm). Therefore, the combined foliar application of GA₃ 100 ppm and NAA 40 ppm (T₈) is recommended for improving the overall growth, productivity, fruit quality, and profitability of strawberry cv. Winter Dawn under controlled environmental conditions.

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