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"Effect of NAA and GA_3 on Growth, Flowering, Fruiting, Yield and Quality of Strawberry (*Fragaria* × *ananassa* Duch.) cv Winter Dawn"

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ABSTRACT

The present investigation was carried out during 2021-22 at Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh. The experiment used a Randomized Block Design and was repeated three times with nine treatments, including NAA (20, 30, 40 and 50 ppm), GA_3 (25, 50, 75 and 100 ppm) and control (Water spray). The results revealed that plants treated with GA_3 100 ppm showed an increase in all the vegetative growth , flowering, fruiting, yield and quality characteristics viz., plant height (18.40 cm), numbers of leaves (20.53), plant spread (26.33 cm) in N-S direction and (26.70 cm) in E-W direction, earlier flower initiation (30.47 days), earlier fruit set (6.93 days), flowers per plant (27.40), number of fruit set per plant (25.00), total fruits per plant (20.97), yield per plant (476.33 g), yield q/ha (238.31 q/ha). Similarly the physical quality characteristics of strawberry viz. the fruit length (48.52 mm), fruit width (43.32 mm), fruit volume (30.00 cc) and fruit weight (45.08 g) were also observed maximum by the application of T_9 (GA_3 100 ppm). The chemical quality characteristics in terms of total soluble solids (9.28 °Brix) show the best result in T_7 (GA_3 50 ppm), the acidity of the fruit (0.60%) was comparatively less in T_8 (GA_3 75 ppm). Whereas the ascorbic acid content (60.66 mg/100 g pulp) was highest in T_9 (GA_3 100 ppm) and the highest benefit: cost ratio (4.76:1) was also observed in T_9 GA_3 100 ppm.

Keywords Strawberry, NAA, GA_3, Growth, Flowering.

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INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) is a commonly cultivated hybrid plant of the Fragaria genus, which belongs to the Rosaceae family. The cultivated varieties are octaploid (2n = 56) in nature and were developed in France during the 17th century from two North American species, *Fragaria chileonsis* and

Fragaria verginiana.

Strawberry is one of the world's most appealing, delicious, and nutritious fruit crops and it is consumed in great numbers both fresh and cooked. It is a valuable fruit crop with a lot of potential for development near major cities and fruit preservation plants. It has become extremely popular in modern times as a result of its better taste and appearance, as well as its health benefits. It is a nutrient-dense fruit with 89–90% moisture, 0.7-9.2 g protein, 8.4–9.2 g carbohydrates and 0.5 g fat. It's high in vitamin C (40-120 mg per 100 g of berries), vitamin A (60 IU per 100 g) and minerals like phosphorus, potassium, calcium, and iron (Sharma 2002). The fruit contains approximately 0.5 % pectin and the flavor is due to the presence of volatile esters.

Strawberries are the fruit that delivers the fastest returns in the least amount of time. It is a monoecious, short-day, fast-growing fruit plant that grows as an annual in the subtropics and as a perennial in the temperate zones. Strawberry is grown in about 75 nations at the moment. It was first introduced in India in the early 1960s, but due to the perishable nature of the fruit, it failed to gain popularity. However, due to its increased profitability and remunerative rates, its cultivation has gained traction in recent years and has become the preferred fruit crop of Indian farmers. Maharashtra is India's most populous and productive state, followed by Haryana, Punjab, Uttar Pradesh, Jammu and Kashmir, Uttrakhand and Himachal Pradesh's lower hills.

Plant growth regulators (PGRs) have been shown to improve yield and quality in a variety of fruits. PGRs are chemical substances, either manufactured or natural, that alter plant physiological processes at very low concentrations. Although some plant growth regulators are created endogenously, they occasionally need to be supplemented exogenously for additional stimulus in short-term crops such as strawberries, which require rapid responses to improved growth, flowering, fruit set, yield and quality. GA_3 promotes cell division, a number of plant development mechanisms and encourages numerous desirable effects such as plant height, uniform flowering, reduced time to flowering, increased flower number, and fruit size (Srivastava and Srivastava 2007). GA_3 has a beneficial effect on fruit setting, increasing total yield and fruit quality, assisting in cell elongation and cell enlargement, increasing vegetative growth, and shortening the time to maturity. The use of NAA extends flowering time and improves fruit output and quality. In strawberry fruits, it also increases fruit size, delays ripening and boosts anthocyanin accumulation.

MATERIALS AND METHODS

The experiment entitled "Effect of NAA and GA_3 on growth, flowering, fruiting yield and quality of strawberry (*Fragaria* × *ananassa* Duch.) cv Winter Dawn" was carried out in open field conditions and conducted at the Horticulture Research Farm of the Department of Horticulture, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh during the years 2021–2022. The area is situated on the southern edge of Prayagraj on the right bank of the Yamuna at Rewa road, at a distance of about 6 km from Prayagraj city. It is situated at 25°.8 N latitude and 81°.50 E longitude, at an elevation of 98 meters above sea level. The current study used a Randomised Block Design (RBD) with nine treatments and three replications. T_1-Control T_2-NAA 20 ppm, T_3-NAA 30 ppm, T_4-NAA-40 ppm, T_5-NAA 50 ppm, T_6-GA_3-25 ppm, T_7-GA_3 50 ppm, T_8-GA_3 75 ppm, and T_9-GA_3 100 ppm. During the last week of October, strawberry runners of almost equal size were transplanted at a spacing of 30 cm × 60 cm. At 15 days after transplanting, a foliar spray of aqueous solution of NAA and GA_3 was sprayed on the plant's upper surface with a knap sack sprayer connected with a fine nozzle that created mist droplets. Data was collected for various vegetative growth, flowering, fruiting, yield and quality characteristics. Plant height (cm), plant spread (cm) were measured with the help of a meter scale and expressed in (cm) and the number of leaves were counted from completely formed leaves produced by each plant to get the total number of leaves from five randomly selected. The days to the first flowering were recorded from the period between the date of planting and the date of first flower opening, days taken to first fruit set was calculated from the date of flower opening to the date of fruit setting. The number of flowers per plant, number of fruit set per plant and total fruits per plant were counted from five randomly

selected plants.

RESULTS AND DISCUSSION

Growth parameters

Plant height

The maximum plant height (18.40 cm) was recorded in T_9 (GA_3 100 ppm) and followed by T_7 (GA_3 50 ppm) with (17.83 cm) whereas the minimum plant height was observed in T_1 (control) as shown in Table 1. The fact that GA_3 increases vegetative development through active cell division and elongation, as well as a proportional rise in stem length, could explain the increase in strawberry plant height. Similar findings were also reported by Tripathi and Shukla (2006), Kumar and Tripathi (2009), Singh and Tripathi (2010), Singh and Singh (2009), Prasad *et al*. (2012), Palei *et al*. (2016), Dubey *et al*. (2017), Kaur *et al*. (2018), Paikra *et al*. (2018) and Sood *et al*. (2018) in strawberry.

Number of leaves per plant

The treatment T_9 (GA_3 100 ppm) produced the highest number of leaves (20.53) and followed by T_7 (GA_3 50 ppm) with (19.67) whereas the minimum number of leaves (17.93) was observed in T_1 (control) as shown in Table 1. The involvement of gibberellic acid and nutrients in plant metabolic processes, photosynthetic activity, glucose and protein metabolism efficiency could explain the rise in leaf number. They may also aid cell division, elongation, and growth of meristamatic tissue, as well as force plants to create more leaves due to increased photosynthates. Similar findings were also Tripathi and Shukla (2006), Kumar and Tripathi (2009), Singh and Tripathi (2010), Prasad *et al*. (2012), Palei *et al*. (2016), Dubey *et al*. (2017), Kaur *et al*. (2018), Paikra *et al*. (2018), Sood *et al*. (2018) and Rathod *et al*. (2021) in strawberry.

Plant spread (cm) in north-south and east –West direction

The maximum plant spread (26.33 cm) in north-south and (26.70 cm) in east-west direction was recorded in T_9 (GA_3 100 ppm) followed by T_8 (GA_3 75 ppm) with (25.83 cm) in north-south and (26.17 cm) in east – west direction, whereas minimum plant spread (22.80 cm) in north – south and (23.70 cm) in east – west was observed in T_1 control as shown in Table 1. Cell division, cell elongation, and cell enlargement, as well as a corresponding rise in petiole length, could explain the increase in plant spread. Similar findings were also reported by Prasad *et al*. (2012), Paikra *et al*. (2018), Sood *et al*. (2018) and Rathod *et al*. (2021) in strawberry.

Flowering and fruiting parameters

Days to first flowering

Earliest flowering (30.47 days) was recorded in T_9 (GA_3 100 ppm) followed by T_5 (NAA 50 ppm) with (32.67 days) and late flowering (38.07 days) was recorded in T_1 (Control) as shown in Table 1. Early flower initiation means that the plant receives all of the necessary nutrients from a balanced hormone spray, allowing for early flowering in the strawberry. This could be related to a reduced flowering duration due to the increased effect of NAA and GA_3 on cell division and growth. Similar findings were also reported by Singh and Singh (2006), Singh and Tripathi (2010), Tripathi and Shukla (2006), Prasad *et al*. (2012), Dubey *et al*. (2017) and Sood *et al*. (2018) in strawberry.

Numbers of flowers per plant

The maximum number of flowers per plant (27.40) was recorded in T_9 (GA_3 100 ppm) followed by T_7 (GA_3 50 ppm) with (25.93) and the minimum number of flowers per plant (20.00) was observed in T_1 (Control) as shown in Table 1.The increase in the number of flowers could be owing to hormone treatment that hastened the development of differentiated inflorescences and spurred flowering, or it could be due to carbohydrate accumulation as a result of increased photosynthesis, forcing the plant to produce more flowers. Similar findings were also reported by Singh and Singh (2006), Kumar and Tripathi (2009), Tripathi and Shukla (2009), Singh and Tripathi (2010), Prasad *et al*. (2012), Kaur *et al*. (2018) and Dubey *et al*. (2017) in strawberry.

Days taken to first fruit set

Earliest fruit set (6.93 days) was recorded in T_9 (GA_3 100 ppm) and followed by T_5 NAA 50 ppm with (7.07 days) and the maximum (7.80 days) taken to first fruit set was observed in T_1 (Control) as shown in Table 1. An increase in photosynthetic activity produced by larger and more leaves, as well as an increase in gibberellin and auxin activity that sped the creation of differentiated inflorescence and increased flowering, could explain the early fruit set. Similar findings were also reported by Prasad *et al*. (2012), Palei *et al*. (2016) and Paikra *et al*. (2018) in strawberry.

Number of fruit set per plant

The maximum number of fruits set per plant (25.00) was observed in T_9 (GA_3 100 ppm) followed by T_7 GA_3 50 ppm with (23.53) and the minimum number of fruits per plant (17.80) was observed in T_1 (Control) as shown in Table 1. GA_3 stimulus involvement in fruit set, which comes not only from pollen but also from the ovary, could explain the rise in fruit set. As a result, it's possible that the pollen component acts as a co-enzyme or activator of enzymatic systems in the ovary that release active hormones from storage pools. Similar findings were also reported by Singh and Singh (2005) and Kumar and Tripathi (2009) in strawberry.

Yield parameters

Total fruit per plant

The maximum total fruits per plant (20.97) was ob-

Table 1. Effect of NAA and GA_3 on vegetative growth, flowering, fruiting and yield parameters of strawberry cv. Winter Dawn.

Treatment detailed	Plant height (cm)	Number of leaves /plant	Plant spread (cm) in N-S direction	Plant spread (cm) in E-W direction	Days to first flowering	Number of flowers / plant
	80 DAP	80 DAP	80 DAP	80 DAP		
T_1	16.27	17.93	22.80	23.70	38.07	20.00
T_2	16.50	18.07	23.47	24.10	36.27	20.73
T_3	17.23	18.53	24.00	24.80	35.20	24.20
T_4	17.00	18.33	23.67	24.43	37.13	22.33
T_5	17.33	18.67	24.50	25.20	32.67	23.00
T_6	16.87	18.20	23.70	24.37	36.67	20.53
T_7	17.83	19.67	25.40	25.70	33.20	25.93
T_8	17.47	19.40	25.83	26.17	34.87	22.47
T_9	18.40	20.53	26.33	26.70	30.47	27.40
F-Test	S	S	S	S	S	S
SE (m)±	0.22	0.42	0.42	0.45	0.82	1.55
CD at 5%	0.66	1.27	1.26	1.34	2.39	4.64

Table 1. Continued.

Treatment detailed	Days taken to first fruit set	Number of fruit set/ plant	Total fruits/ plant	Yield per plant (g)	Yield (q/ha)
T_1	7.80	17.80	14.97	327.28	163.64
T_2	7.40	18.40	15.30	348.32	174.14
T_3	7.33	21.93	18.17	403.72	201.86
T_4	7.53	20.07	16.73	372.50	186.25
T_5	7.07	20.80	17.30	395.50	197.75
T_6	7.60	18.27	15.17	342.06	171.03
T_7	7.13	23.53	19.80	434.94	217.47
T_8	7.33	20.07	16.67	399.78	199.89
T_9	6.93	25.00	20.97	476.61	238.31
F-Test	S	S	S	S	S
SE (m)±	0.15	1.52	1.24	20.63	10.31
CD at 5%	0.46	4.55	3.73	61.86	30.92

served in T_9 (GA_3 100 ppm) followed by T_7 GA_3 50 ppm with (19.80) and the minimum total fruits per plant (14.97) was observed in T_1 (Control) as shown in Table 1. This may be due to faster translocation and mobilization of stored metabolites or photosynthates from source to sink, which could explain that GA_3 boosted the number of fruits per plant. Similar findings were also reported by Singh and Singh (2005), Prasad *et al*. (2012) and Kaur *et al*. (2018) in strawberry.

Yield per plant (g)

The maximum fruit yield per plant (476.61 g) was recorded in plants treated with T_9 GA_3 100 ppm followed by GA_3 50 ppm with (434.94 g) whereas minimum yield per plant (327.28 g) was observed in T_1 control as shown in Table 1. The increase in yield per plant might be due to the increased fruit set per plant, fruit length, fruit width, fruit weight as well as fruit volume. Lopez *et al*. (1989) also recorded increased yield with increase in GA_3 concentration. Similar findings were also reported by Singh and Singh (2006), Kumar and Tripathi (2009), Singh and Tripathi (2010), Prasad *et al*. (2012), Rajbahar *et al*. (2015), Dubey *et al*. (2017) and Kaur *et al*. (2018) in strawberry.

Yield (q/ha)

The highest yield (238.31 q/ha) was recorded in T_9 (GA_3 100 ppm) followed by T_7 (GA_3 50 ppm) with (217.47 q/ha) and the minimum yield (163.64 q/ha) was observed in T_1 (Control) as shown in Table 1. Increased flowering and fruit set, as well as larger fruit weight and size, may account for the higher yield. GA_3 also enhanced the availability of nutrients and other chemicals to the fruits, which is critical for their correct growth and development, resulting in larger fruits and higher yields. Similar findings were also reported by Singh and Singh (2009), Prasad *et al*. (2012) and Rajbahar *et al*. (2015) in strawberry.

Physical quality parameters

Fruit length (mm)

The maximum fruit length (48.40 mm) was observed in T_9 (GA_3 100 ppm) and followed by T_7 (GA_3 50 ppm) with (48.27 mm). However the minimum fruit length (45.73 mm) was observed in T_1 (Control) as shown in Table 2. The increase in fruit length could be owing to higher carbohydrate levels and GA_3 could have encouraged cell division and cell elongation, resulting in maximum fruit length. Similar findings were also reported by Kumar and Tripathi (2009), Singh and Singh (2009), Singh and Tripathi (2010) and Prasad *et al*. (2013) in strawberry.

Fruit width (mm)

The maximum fruit width (43.32 mm) was recorded in T_9 (GA_3 100 ppm) followed by T_8 (GA_3 75 ppm) with (43.14 mm). However the minimum fruit width (40.99 mm) was observed in T_1 (Control) as shown in Table 2. The increase in fruit width seen in this study could be attributed to GA_3 treated plants' enhanced photosynthetic ability, which favored and increased dry matter accumulation. Similar findings were also reported by Kumar and Tripathi (2009), Singh and Tripathi (2010) and Prasad *et al*. (2013) in strawberry.

Fruit volume (cc)

The berries of significantly higher fruit volume (30.00 cc) was observed in T_9 (GA_3 100 ppm) followed by T_8 (GA_3 75 ppm) with (29.67cc) whereas the minimum fruit volume (26.33 cc) was observed in T_1 (control) as shown in Table 2. Increased growth rate by cell division and cell expansion appears to be the physiological reason for increased fruit volume. Faster loading and mobilization of photoassimilates into fruits could be aided by plant growth regulators. Similar findings were also reported by Singh and Singh (2006) Tripathi and Shukla (2010) in strawberry.

Fruit weight (g)

The maximum fruit weight (45.08 g) was observed in T_9 GA_3 100 ppm, followed by T_7 (GA_3 50 ppm) with (44.63 g). However the minimum fruit weight (41.73 g) was noticed in T_1 (Control) as shown in Table 2. Exogenous administration of GA_3 enhanced fruit growth and final size by enhancing cell elongation or expansion, which could explain the maximum fruit weight. GA_3 stimulated the growth of all vegetative

Table 2. Effect of NAA and GA_3 on physical, chemical quality parameters of fruits and B: C ratio of strawberry cv Winter Dawn.

Treatment detailed	Fruit length (mm)	Fruit width (mm)	Fruit volume (cc)	Fruit weight (g)	Total soluble solids (°Brix)	Acidity (%)	Ascorbic acid (mg /100 g pulp)	B:C ratio
T_1-Control	45.73	40.99	26.33	41.73	8.22	0.81	52.92	3.02
T_2-NAA 20 ppm	46.13	41.19	27.56	42.26	8.50	0.77	53.91	3.27
T_3-NAA 30 ppm	47.33	41.93	28.22	43.21	8.72	0.74	55.14	3.94
T_4-NAA 40 ppm	46.31	42.32	27.89	42.56	8.84	0.73	54.13	3.56
T_5-NAA 50 ppm	47.81	42.11	28.56	43.90	8.97	0.70	57.02	3.83
T_6-GA3 25 ppm	46.70	41.49	27.67	42.77	8.44	0.76	54.70	3.18
T_7-GA3 50 ppm	48.27	42.92	29.11	44.63	9.28	0.66	58.01	4.30
T_8-GA3 75 ppm	47.20	43.14	29.67	44.14	9.17	0.60	58.83	3.85
T_9-GA3 100 ppm	48.52	43.32	30.00	45.08	9.00	0.63	60.66	4.76
F-Test	S	S	S	S	S	S	S	-
SE (m)±	0.58	0.52	0.47	0.43	0.22	0.04	0.79	-
CD at 5%	1.75	1.55	1.42	1.29	0.65	0.13	2.36	-

portions, resulting in more food material being produced for fruit development by plants and fruits of maximum weight. The improved photosynthetic ability of plants treated with GA_3 at 100 ppm during the current study could explain the rise in fruit size and weight. Similar findings were also reported by Singh and Singh (2009), Tripathi and Shukla (2010), Prasad *et al*. (2013) and Rajbahar *et al*. (2015) in strawberry.

Chemical quality parameters

Total soluble solids (°Brix)

The fruits of significantly higher TSS (9.28° Brix) were produced from the plants treated with T_7 (GA_3 50 ppm) and followed by GA_3 75 ppm with (9.17 °Brix) and the minimum TSS (8.22° Brix) was recorded in T_1 (control) as shown in Table 2 .The use of NAA and GA_3 influenced the physiological process, which hydrolyzed starch and aided metabolic activity during the conversion of available starch to sugar, possibly increasing TSS. Similar finding was also reported by Kumar *et al*. (2013) in strawberry and he observed that application of GA_3 50 ppm resulted significant improvement in Total soluble solids (°Brix).

Acidity (%)

The minimum acidity (0.60 %) was recorded in the fruits produced from the plants treated with T_8 (GA_3 75 ppm) followed by T_9 GA_3 100 ppm with (0.63 %) whereas the maximum acidity (0.81%) was recorded in T_1 (control) as shown in Table 2.The decrease in acidity caused by growth regulators could be attributed to metabolic processes involving the rapid conversion of organic acids to sugars and sugar derivatives. Similar finding was also reported by Mastuane *et al*. (2016) in strawberry and he observed that application of GA_3 75 ppm resulted significant decrease in Acidity %.

Ascorbic acid (mg/100 g)

The maximum ascorbic acid content in fruits (60.66 mg/100 g) was recorded in T_9 (GA_3 100 ppm) and followed by T_8 (GA_3 75 ppm) with (58.83 mg/100 g), while the minimum ascorbic acid content (52.92 mg/100 g) was observed in T_1 (Control) under the present experiment as shown in Table 2. The increase in ascorbic acid with gibberellic acid could be owing to gibberellic acid's catalytic influence on its biosynthesis from its precursor glucose-6-phosphate, or it could be due to ascorbic acid's prevention of its conversion to dehydro-ascorbic acid, or both. Similar findings were also reported by Singh and Singh (2006), Singh and Singh (2009), Kumar and Tripathi (2009), Prasad *et al*. (2013), Kumar *et al*. (2013) and Dubey *et al*. (2017) in strawberry.

Benefit: cost ratio

The highest benefit: cost ratio (4.76:1) was recorded from the treatment T_9 (GA_3 100 ppm), followed by T_7 (GA_3 50 ppm) with (4.30:1) and the minimum benefit:

cost ratio (3.02:1) was recorded in T_1 (control) as shown in Table 2. Similar findings were also reported by Prasad *et al*. (2012) in strawberry.

CONCLUSION

From this study it is concluded that plants treated with GA_3 100 ppm considerably boosted the growth, flowering, fruit production and quality of strawberry cv Winter Dawn with the highest Benefit: Cost ratio. On the basis of the foregoing data, it can be stated that in the Prayagraj agro-climatic conditions, strawberry plants should be treated with GA_3 100 ppm to produce a significantly higher yield and better quality berries.

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