Effect of Plant Growth Regulators on Growth, Yield and Quality of Strawberry (*Fragaria × ananassa* Duch.) cv. Winter Dawn.

ABSTRACT

Strawberries are small, typically heart-shaped fruits with a bright red skin. Strawberries are not only delicious but also packed with nutrients. Strawberries are versatile and can be enjoyed in various ways. They are commonly used in desserts like pies, cakes, and ice cream. The present investigation was laid out on the experimental site of Department of Horticulture, Sam Higginbottom University of Agriculture Technology & Sciences, Naini, Prayagraj (UP), during 2022. This experiment was conducted to evaluate the best treatment among GA_3, NAA, Brassinosteroid on strawberry variety winter dawn. The experiment was laid out in Randomized Design having 10 treatments and replicated 3 times. The effects of these treatments were noted on number of leaves, plant height, flowering, fruiting and fruit quality and yield attributes of Strawberry. The results of experimentation confirmed the efficiency of growth regulators for better fruit growth attributes, yield and quality of strawberry variety Winter Dawn. The study revealed that at BRs @100 ppm significantly increased the size, quality of the fruits as well as yield per plant and yield per hectare. Maximum TSS was found in the treatment T_9 BRs @100 ppm. significantly increased number of fruits per plant. Among various concentrations of growth regulators, the treatment BRs @100 ppm was found significantly superior over all other treatments.

Keywords: *GA_3, NAA, Brassinosteroid, Strawberry.*

INTRODUCTION

Fruits are an essential component of the human diet, offering both commercial value and nutritional significance (Prasanna *et al*.,2007)[8]. They provide variety, taste, aesthetic appeal, and nutritional benefits to our meals. Fruits are the edible products of perennial higher plants, characterized by their high-water content, soft texture, and sweet, sour, or semi-astringent flavours. Due to their exotic flavours and tastes, fruit production has gained considerable attention worldwide. Major fruits contributing to global production include citrus, grapes, banana, apple, mango, pineapple, pear, plum, papaya, date, strawberry, apricot, and avocado. Strawberry (*Fragaria × ananassa* Duch**.)** is an aggregate fruit, belongs to the family Rosaceae. The cultivated strawberry was originated from the hybridization of two American species viz., *Fragaria × chiloensis* Duch. and *Fragaria × virginiana* Duch. Strawberry (*Fragaria ×ananassa* Duch.) is one of the most popular soft fruits cultivated in plains as well as in the hills up to an elevation of 3000 m in humid or dry regions. It has attained the status of being one of the most important soft fruits of the world after grapes. Strawberry is one of the most popular fruits in the human diet. Strawberries (*Fragaria spp*.) are highly popular as fresh fruits due to their rich vitamin C and ellagic acid content. They are considered one of the most beloved berries, known for their antioxidant, anticancer, anti-inflammatory, and anti-neurodegenerative properties. These beneficial properties are largely attributed to the high polyphenolic content of strawberries, particularly anthocyanins, which are the most abundant type of polyphenols in strawberry fruits, along with flavonoids, phenolic acids, and vitamin C (Cordenunsi *et al*., 2005)[2]. Numerous dry achenes are attached to the outside of the fruit-flesh; they appear to be

seeds but each is an ovary of a flower, with a seed inside Strawberry is an octoploid self-pollinated plant species with chromosome number 2n=8x=56 (Folta and Barbey, 2019)[4]. It is grown in temperate countries and biennial plant. The strawberry and its juice are freely consumed for its great taste, nutritional benefit, and flavor content. At present its productivity is 8.9 t/ha fruit per year in world (Anonymous, 2021)[1]. As per National Institute of Nutrition (NIN, 2008), nutritional composition of beetroot constituted Moisture (91 %), Protein (1.7 g), Crude fibre (2.9 g), Carbohydrates (7.68 g), Calories (33 Kcal), Calcium (16 mg/100g), Phosphorus (24 mg/100g) and Iron (0.41 mg), Vitamin B_3 (0.386 mg/100g), Vitamin C (58.8 mg/100g) and Magnesium (13 mg/100g). Strawberries contain a modest amount of essential unsaturated fatty acids in the achene (seed) oil. Pelargonidin-3-glucoside is the major anthocyanin in strawberries and cyanidin-3-glucoside is found in smaller proportions. Although glucose seems to be the most common substituting sugar in strawberry anthocyanins, rutinose, arabinose, and rhamnose conjugates have been found in some strawberry cultivars (Giampieri *et al*., 2012)[5]. Strawberries, are one of the important fruit crops in the world, have gained popularity among Indian growers near towns and cities due to their high profitability and remunerative prices, leading to a significant increase in their cultivation area and production in recent years (Sharma, 2006)[9]. In India, strawberry cultivation is mainly concentrated in regions such as Dehradun, Nainital (Uttarakhand), Solan, Kullu (Himachal Pradesh), Srinagar (Jammu and Kashmir), and the hills of Darjeeling (West Bengal). Strawberries have specific requirements for optimal growth and development. They thrive in a day temperature range of 22°C to 23°C and a night temperature range of 7°C to 13°C. Frost and winter injury can significantly reduce berry yield. The ideal soil type for strawberry cultivation is sandy loam with a pH range of 5.5 to 6.5 (*Source: NHB,* Ministry of Agriculture & Farmers Welfare, Government of India, 2020-21)[6]. The growth and development of strawberry plants, as well as the yield and quality of fruits and runners, are greatly influenced by the fertility, moisture, drainage, and microbial status of the upper layer of soil. Many plants growth regulating compounds, such as auxins, cytokinin, and gibberellins, have been used in various crops to achieve larger fruit size (Sharma, 2006)[9]. However, evaluating the efficacy of such product applications based solely on fruit enlargement may not fully capture the impact on biochemical quality characteristics. The role of auxin in strawberry fruit development has been well-established, as it is responsible for receptacle enlargement and fruit size growth. Nitsch (2005)[7] demonstrated that hormonal compounds produced by the developing seeds were associated with fruit growth in strawberries. Brassinosteroid have been found to promote photosynthesis accumulation in fruits, increase RNA and DNA content, enhance protein synthesis, and boost polymerase activity. The application of Brassinosteroid has been linked to improved efficiency of the photosynthesis process in sprayed plants, resulting in increased yield. In this article, we will explore the role of Brassinosteroid in plant growth and development, and their potential effects on fruit production and yield.

MATERIALAND METHODS

The present investigation was done to understand the effect of GA_3, NAA, Brassinosteroid on yield and quality of strawberry variety Winter dawn. The experiment was carried out at Horticultural Research Farm (HRF), Department of Horticulture, Naini Agricultural Institute SHUATS, Prayagraj, U.P., during the *Rabi* season of 2021-22. Prayagraj located at 25.57ºN latitude 81.51º E longitude and 98 meter above the sea level. The experimental site was level land with sandy loam soil of uniform fertility status with low clay and high sand percentage values of Soil samples were collected at random spots from depth 0-30 cm and the soil was analysed

for pH, electrical conductivity (EC), organic carbon, available nitrogen, available phosphorus, and available potassium. The different combination doses of GA_3, NAA, Brassinosteroid mentioned in table 1 and replicated thrice. The data were statistically analysed (by the method suggested by Fisher and Yates 1963)[3]**.** The treatments comprised of T_0 (Control), T_1 (NAA @ 10 ppm), T_2 (NAA @ 25 ppm), T_3 (NAA @ 50 ppm), T_4 (GA_3 @ 10 ppm), T_5 (GA_3 @ 25 ppm), T_6 (GA_3 @ 50 ppm), T_7 (BRs @ 25 ppm), T_8 (BRs @ 50 ppm) and T_9 (BRs @ 100 ppm). The experimental field was brought to fine tilth by ploughing and harrowing by tractor. The experimental site was divided into small plots of 2m ×2m dimensions with 30 cm bunds between the plots. Irrigation channels of 50 cm width were provided between two rows of plots. Planting of runners were done between the rows of 60 cm and between the plants of 30 cm spacing was maintained and plants were planted in the evening. After planting the light irrigation was done to prove the sufficient soil moisture to the young plant. Foliar application of PGR's viz, Gibberellic acid, Naphthalene Acetic acid Brassinosteroid. were applied as per the treatment. Observations were recorded at different stages of growth periods for characters like Total number of leaves, Plant height, plant spread, earliness parameters like days to flowering and fruiting, yield parameters like total fruit per plant, fruit length, fruit diameter, weight, and total fruit yield. Quality parameters like pH, acidity and TSS was also calculated.

RESULTS AND DISCUSSION

A) Growth Parameters

Data from the table 2 and 3 depicts the growth parameters observed for strawberry.

1. Total Number of leaves per plant

Maximum No of Leaves [6.25 (30DAP), 9.9 (60 DAP), 20.25 (90 DAP), 28.50 (120 DAP)] was recorded in treatment T_9 (BRs @ 100 ppm) and Minimum was recorded in Treatment T_0 (Control) [2.83 (30 DAP), 5.08 (60 DAP), 9.25 (90 DAP), 17.50 (120 DAP)].

2. Plant height

Maximum plant Height [6.56 cm (30 DAP), 8.22 cm (60 DAP), 11.16 cm (90 DAP), 14.91 cm (120 DAP)] was recorded in treatment T_9 (BRs @ 100 ppm) and Minimum was recorded in Treatment T_0 (Control) [3.95 cm (30 DAP), 5.54 cm (60 DAP), 7.12 cm (90 DAP), 8.89 cm (120 DAP)].

3. Plant spread (cm)

Effect of treatment T_9 (BRs @ 100 ppm) recorded the maximum plant spread [E-W= 13.52 cm] [N-S=13.88 cm] (30DAP), [E-W= 16.85 cm] [N-S=16.91 cm] (60 DAP) [E-W= 21.31 cm] [N-S=21.87 cm] (90 DAP), [E-W= 25.13 cm] [N-S=25.25 cm] (120 DAP)] over all other treatments where-as Treatment T_0 (Control) [E-W= 6.00 cm] [N-S= 6.05 cm](30 DAP), [E-W= 9.15 cm] [N-S= 9.09 cm] (60 DAP), [E-W= 10.55 cm] [N-S= 10.58 cm](90 DAP), E-W= 13.92 cm] [N-S= 13.93 cm] (120 DAP)] was found having significantly minimum plant spread. The use of GA3 (gibberellic acid), auxin, and brassinosteroids in strawberry cultivation contributes to better plant growth for several reasons. GA_3 promotes stem elongation, enhances flowering, and increases fruit size. Auxins stimulate root development and promote overall plant growth and vigour. Brassinosteroids play a crucial role in cell elongation, cell division, and stress tolerance, leading to improved plant growth, larger leaves, and enhanced fruit quality. The combined effects of these plant growth regulators result in improved yields,

healthier plants, and better overall growth in strawberry cultivation. Similar results have also been reported by Thakur *et al.,* (2015)[10] in Strawberry.

B) Phenological characters

Data from the table 4 depicts the phenological characters observed for strawberry.

1. Days to first flowering and days to first fruiting

Minimum number of days for flower bud initiation to flowering [48.66 days] was recorded in treatment T_9 (BRs @ 100 ppm) and Maximum was recorded in Treatment T_0 (Control) [62.91 days]. Minimum number of days to first fruiting [68.08 days] was recorded in Treatment T_9 (BRs @ 100 ppm) and Maximum days to fruiting was recorded in Treatment T_0 (Control) [83.50 days]. Earliness is essential requirement for crop maturity. PGRs can promote early flowering in plants by providing essential nutrients, natural plant growth hormones, and stress mitigation. Nutrient availability of essential nutrients such as nitrogen, phosphorus, and potassium stimulate early flowering. Hormones like auxins and cytokinin promote the production of flower buds. Finally, stress mitigation helps to cope with unfavourable environmental conditions, promoting early flowering. Similar findings were reported by Similar results have also been reported by Thakur *et al*., (2015); Jayalakshmi *et al.,* (2017); and Khatoon *et al*., (2020) in Strawberry.

C) Yield parameter

Data from the table 4 depicts the yield characters observed for strawberry.

1. Number of flowers per plant and number of fruits per plant

Maximum number of flowers per plant [22.08 flowers] was recorded in Treatment T_9 (BRs @ 100 ppm) and Minimum was recorded in Treatment T_0 (Control) [12.00 flowers]. Maximum number of fruits per plant [20.58 fruits] was recorded in Treatment T_9 (BRs @ 100 ppm) and Minimum was recorded in Treatment T_0 (Control) [11.25 fruits].

2. Fruit length, Fruit diameter and Fruit weight

Maximum Fruit Length [6.07 cm] was recorded in Treatment T_9 (BRs @ 100 ppm) and Minimum was recorded in Treatment T_0 (Control) [3.08 cm]. Maximum Fruit Diameter [3.98 cm] was recorded in Treatment T_9 (BRs @ 100 ppm) and Minimum was recorded in Treatment) T_0 (Control) [2.97 cm]. Maximum Fruit Weight [31.55 g] was recorded in Treatment T_9 (BRs @ 100 ppm) and Minimum was recorded in Treatment T_0 (Control) [11.13 g].

3. Total production per plant

Maximum number of Production per plant [345.36 g] was recorded in Treatment T_9 (BRs @ 100 ppm) and Minimum was recorded in Treatment T_0 (Control) [178.90 g]. PGRs promote an increased number of fruits due to several reasons. Firstly, they provide a steady release of essential nutrients like nitrogen, phosphorus, and potassium that are essential for fruit development and maturation. Secondly, plant growth hormones such as auxins and cytokinin, which can stimulate the production of fruit buds and increase the number of fruits per plant. Thirdly, they can improve the health and activity of pollinators like bees and butterflies, which can increase the rate of fruit set. Finally, they help plants to cope with environmental stresses like drought or disease, which can lead to more consistent fruit production and

higher yields. Results were in accordance with the findings of Thakur *et al.,* (2015); Jayalakshmi *et al.,* (2017); and Khatoon *et al*., (2020) in Strawberry.

D) Quality parameter

1. TSS, Acidity and pH

Maximum TSS [6.25 ^{0}Brix] was recorded in Treatment T_9 (BRs @ 100 ppm) and Minimum was recorded in Treatment T_0 (Control) [2.83 ^{0}Brix]. Lowest Acidity % [0.58%] was recorded in Treatment T_9 (BRs @ 100 ppm) and Highest was recorded in Treatment T_0 (Control) [0.95%]. The highest pH of the fruit juice (4.70) was recorded in T_9 (BRs@100ppm) followed by the treatment T_8 (4.40). The minimum pH of the fruit juice (3.07) was recorded in control (T_0). Results were in accordance with the findings of Thakur *et al.,* (2015); Jayalakshmi *et al.,* (2017); and Khatoon *et al*., (2020) in Strawberry. Data from the table 4 depicts the quality characters observed for strawberry.

Summary and Conclusion

From the results obtained during the present investigation with different treatment of GA_3, NAA and Brassinosteroid, on vegetative growth, flowering, yield and quality of strawberry cv. Winter Dawn, it is concluded that plants treated with (BRs @100 ppm) significantly increased the number of leaves height of plant, plant spread, number of leaves, duration of harvesting, days taken to first flower, number of flowers, days taken to fruit set, number of fruits per plant and fruit yield per plant. So far as the yield, the response of strawberry plants treated with (BRs @100 ppm) plants produced higher yield. TSS of (BRs @100 ppm) was higher as compared to other treatments. Total sugar of fruits treated with (BRs @100 ppm) were higher than the other treatments. Minimum titratable acidity was recorded in plants treated with (BRs @100 ppm).

Table 2 Performance of different doses of GA_3, NAA, Brassinosteroid on number of leaves and plant height of strawberry.

Treatment symbol	Treatment Details	No of leaves (30DAP)	No of leaves (60DAP)	No of leaves (90 DAP)	No of leaves (120DAP)	Plant height (30DAP) (cm)	Plant height (60DAP) (cm)	Plant height (90DAP) (cm)	Plant height (120DAP) (cm)
T_0	Control	2.83	5.08	9.25	17.5	3.95	5.54	7.12	8.89
T_1	NAA @ 10 ppm	3.41	5.1	11.75	18.75	4.09	5.92	7.83	9.7
T_2	NAA @ 25 ppm	3.66	5.3	13.25	19.75	4.06	6.2	7.99	9.81
T_3	NAA @ 50 ppm	4.25	5.5	12	18.75	4.3	6.19	8.22	9.96
T_4	GA_3 @ 10 ppm	4	5.25	12.5	18.25	4.31	6.2	8.04	9.98
T_5	GA_3 @ 25 ppm	3.66	5.8	11.75	19.75	4.27	6.41	8.31	9.88
T_6	GA_3 @ 50 ppm	3.75	6.3	13	20	4.43	6.4	8.41	9.68
T_7	BRs @ 25 ppm	3.91	5.8	11.25	19.75	4.4	6.25	8.05	10.12
T_8	BRs @ 50ppm	5	8.5	18	24.5	5.6	7.75	9.43	12.54
T_9	BRs @ 100ppm	6.25	9.9	20.25	28.5	6.56	8.22	11.16	14.91
F-Test		**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
S.E.(m) (±)		**0.14**	**0.23**	**0.3**	**0.58**	**0.23**	**0.2**	**0.2**	**0.3**
C.D. (5%)		**0.44**	**0.7**	**0.9**	**1.72**	**0.69**	**0.61**	**0.59**	**0.91**
C.V.		**6.32**	**6.58**	**4.19**	**4.95**	**0.79**	**5.51**	**4.1**	**5.06**

Table 3 Performance of different doses of GA_3, NAA, Brassinosteroid on plant spread of strawberry.

Treatment symbol	Treatment Combination	Plant spread (30 DAP) (cm)		Plant spread (60 DAP) (cm)		Plant spread (90 DAP) (cm)		Plant spread (120 DAP) (cm)	
		E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S
T_0	Control	6	6.05	9.15	9.09	10.55	10.58	13.92	13.93
T_1	NAA @ 10 ppm	8.65	8.66	10.83	11.05	13.8	13.67	15.7	16.05
T_2	NAA @ 25 ppm	9.62	9.54	11.44	11.48	13.72	14.38	19.64	19.47
T_3	NAA @ 50 ppm	9.95	9.85	12.425	12.09	14.55	14.3	19.85	20.18
T_4	GA_3 @ 10 ppm	10.2	10.167	13	13.13	14.18	14.33	20.11	20.32
T_5	GA_3 @ 25 ppm	9.63	9.9	12.2	12.06	14.03	14	19.56	20.08
T_6	GA_3 @ 50 ppm	10	10.06	12.01	12.02	14.1	14.77	18.84	19.76
T_7	BRs @ 25 ppm	9.54	9.5	13.12	13.3	14.62	15.04	20.35	20.5
T_8	BRs @ 50ppm	11.75	11.98	15	15	19.38	19.75	22.45	22.65
T_9	BRs @ 100ppm	13.52	13.88	16.85	16.91	21.31	21.87	25.13	25.25
F-Test		**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
S.E.(m) (±)		**0.33**	**0.36**	**0.36**	**0.41**	**0.42**	**0.4**	**0.59**	**0.5**
C.D. (5%)		**0.99**	**1.07**	**1.07**	**1.21**	**1.25**	**1.19**	**1.76**	**1.5**
C.V.		**5.88**	**6.31**	**4.96**	**5.63**	**4.87**	**4.57**	**5.25**	**4.43**

Table 4 Performance of different doses of GA_3, NAA, Brassinosteroid on yield and quality parameters of strawberry.

Treatment symbol	Treatment Details	Days to first flowering (days)	Days to first fruiting	No of flowers/plant	No of fruits/plant	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Total fruit production/plant (g/plant)	TSS [°Brix]	Acidity (%)	pH
T_0	Control	62.91	83.5	12.00	11.25	3.08	2.97	11.13	178.90	2.83	0.95	3.07
T_1	NAA @ 10 ppm	58.08	81.08	13.67	12.50	3.33	3.20	16.55	216.23	3.41	0.91	3.57
T_2	NAA @ 25 ppm	56.58	77.91	14.58	13.67	3.81	3.23	17.63	238.83	3.66	0.83	3.80
T_3	NAA @ 50 ppm	55.25	77.08	15.00	14.08	3.98	3.30	19.22	267.98	4.25	0.84	4.10
T_4	GA_3 @ 10 ppm	55.16	76.25	16.08	15.08	4.21	3.26	19.79	278.44	4	0.78	3.97
T_5	GA_3 @ 25 ppm	54.83	75.5	16.67	15.67	4.32	3.39	20.48	283.87	3.66	0.76	4.00
T_6	GA_3 @ 50 ppm	55.25	73.83	17.42	16.42	4.67	3.53	22.73	309.61	3.75	0.72	4.17
T_7	BRs @ 25 ppm	52.75	72.5	18.50	17.50	4.99	3.76	24.39	324.80	3.91	0.63	4.23
T_8	BRs @ 50ppm	50.5	70.25	20.50	19.25	5.43	3.81	28.41	337.48	5	0.60	4.40
T_9	BRs @ 100ppm	48.66	68.08	22.08	20.58	6.07	3.98	31.55	345.36	6.25	0.58	4.70
F-Test		**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**	**S**
S.E.(m) (±)		**0.61**	**0.64**	**0.33**	**0.26**	**0.05**	**0.30**	**0.38**	**1.70**	**0.09**	**0.007**	**0.04**
C.D. (5%)		**0.82**	**1.92**	**0.98**	**0.77**	**0.15**	**0.91**	**1.14**	**5.06**	**0.28**	**0.20**	**0.14**
C.V.		**1.93**	**1.48**	**3.44**	**2.89**	**2.10**	**5.06**	**3.14**	**1.06**	**1.69**	**1.76**	**2.09**

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