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Effect of Foliar Application of Plant Growth Regulators on Growth, Yield and Quality of Strawberry (*Fragaria x ananassa Duch*) cv. Sweet Charlie

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The field experiment was conducted during *rabi* season in the year 2021-2022 at post graduate Horticulture Experimental farm, Department of Horticulture, Naini Agriculture Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh, in order to study the Foliar application of different Plant growth regulators treatments on Strawberry cv. Sweet Charlie. The experiment was laid out in Randomized Block Design (RBD) with 10 treatments and 3 replications. Strawberries were treated with (GA_3, NAA, Triacontanol) were subjected to growth, yield and quality parameters and showed better results in combination treatment T_8(Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) the treatment whereas minimum was observed in T_0(control).

Keywords: Strawberry; plant growth regulators; analysis of variance; mean performance.

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1. INTRODUCTION

Strawberry is a temperate fruit; its production in tropical and subtropical region is drastically low and the high market price. Strawberry is one of the most favored fruit crops among the growers, especially in towns and cities due to its profitable remunerative prices. Therefore, increasing the productivity of strawberry by manipulation of flowering for increased fruit production is important key point research has proved that plant bio-regulators educe biochemical changes in fruit crops, which in turn induce both vegetative and reproductive responses [1,2].

Strawberry being a vegetatively propagated plant and its commercial propagation through Runners. Runner is slender, prostrate branch with long internodes, creeping at the ground surface, rooting at the node and growing into a new plant.

Nutritionally, strawberry is a low calorie carbohydrate fruit but a rich source of vitamin A (60 IU/100g of edible portion), vitamin C (30-120 mg/100g of edible portion), fiber and also has high pectin content (0.55%) available in the form of calcium pectate. Water is a major constituent (90%) of strawberry fruit. Ellagic acid is a naturally occurring plant phenol which has been found to inhibit the cancer disease and asthma through regular consumption

In India, Maharashtra is a leading state in production of strawberry fruit. It is commercially grown in J & K, Maharashtra, Karnataka and Madhya Pradesh etc. Recently, strawberry's cultivation in northern India especially in Haryana, Punjab, Himachal Pradesh and parts of Uttar Pradesh is picking up fast due to availability of market in Delhi and another city. Haryana is the largest producer of strawberry with 2.01 million tonnes production.

Exogenous application of triacontanol has found beneficial effect on chlorophyll contents, photosynthetic rate and chlorophyll fluorescence. Various studies indicate strong evidences that the application of triacontanol applied either to the root medium or to leaves enhanced the growth and yield of crops, including agronomic and horticultural crops as well as medicinal and aromatic crop plants under normal and adverse conditions

Growth regulators play integral roles in controlling the growth, development, metabolism, and morphogenesis of flowering plants. Gibberellic acid (GA3) was demonstrated to induce inflorescence development and flowering and to increase the number of flowers

Napthalene acetic acid is a popular fertiliser in horticultural crops. The vegetative development of citrus trees is dependent on the nutrients applied to both young and maturing trees.

Growth regulating chemicals are becoming important in strawberry for the modification of their vegetative growth, flowering and fruiting affecting total yield and also quality [3,4]. Therefore, growth regulators at optimum doses and proper growth stages are very essential for increasing growth and production in strawberry. Considering the above views this study was conducted with three different concentration of gibberellic acid (GA3), Napthalene acetic acid and Triaconatol to find out the optimum concentration of gibberellic acid for the improvement of fruit size and yield of strawberry.

- The objective of this study is to find out the suitable doses of GA_3, NAA and Triacontanol on the vegetative growth, quality and yield of Strawberry
- To workout the economics of different treatments

2. MATERIALS AND METHODS

2.1 Description of Study Area

The experiment was conducted during *Rabi* season of 2021-22. The experiment was conducted using Randomized Block Design consisting of 9 treatments, 6 plants with three replication in field condition at the department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh. Prayagraj is located in the south eastern part of Uttar Pradesh, India. This region has subtropical Climate with extreme of summer and winter. The temperature falls to as low as $2\text{-}3^0$c during winter season especially in the month of December and January.

2.2 Experimental Design and Treatment Details

T_0 - CONTROL
$T_{1,}$ - GA_3 @ 25 ppm/lt + Triacontanol @ 5.25 ppm/lt
T_2 - GA_3 @ 75 ppm/lt + NAA @ 40ppm/lt

T_3 - GA_3 @ 100ppm/lt + Triacontanol @ 1.25 ppm/lt
T_4 - NAA @ 20 ppm/lt + GA_3 @ 75 ppm/lt
T_5 - NAA @ 40 ppm/lt + Traicontanol @ 3.25 ppm/lt
T_6 - NAA @ 60 ppm/lt + GA_3 @ 25 ppm/lt
T_7 - Triacontanol @ 1.25 ppm/lt + NAA @ 20 ppm/lt
T_8 - Triacontanol @ 3.25 ppm/lt + GA_3 @ 100 ppm/lt
T_9 - Triacontanol @ 5.25 @ ppm/lt + NAA @ 60 ppm/lt

From the transplanting till the maturity and harvest the observations were recorded on different growth parameters viz plant height, number of leaves per plant, plant spread, days taken for 50% flowering, number of flowers per plant, days taken for 50% fruiting, number of fruits per plant, fruit length, fruit width, average fruit weight, fruit yield per plant, plot, hectare, TSS, Acidity, ascorbic acid were recorded and statistically analyzed using analysis of variance as applicable to randomized block design.

3. RESULTS AND DISCUSSION

A. Growth parameters

Plant height

At 30 DAT the highest plant height was recorded in the T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) 10.92cm followed by 10.33 cm with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and lowest plant height 7.16cm was recorded in T_0 control. At 60 DAT the highest plant height was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) 15.75 cm followed by 14.83 cm with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and lowest plant height 11.66cm was recorded in T_0 control. At 90 DAT the highest plant height was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) 21.66 cm followed by 20.83 cm with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and lowest plant height 14.33cm was recorded in T_0 control.

Number of leaves per plant

The observation on number of leaves per plant on strawberry were statistically analyzed. At 30 DAT the maximum number of leaves per plant 9.5 was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) followed by 9.33 with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and minimum number of leaves per plant 6.58 was recorded in T_0 control. At 60 DAT the maximum number of leaves per plant 14.5 was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) followed by 14.1 with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and minimum number of leaves per plant 10.2 was recorded in T_0 control. At 90 DAT the maximum number of leaves per plant 21.3 was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) followed by 20.3 with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and minimum number of leaves per plant 15.1 was recorded in T_0 control.

Plant spread

The maximum plant spread 26.33 cm was significantly recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) followed by 25.16 cm with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and minimum plant spread 19.16 cm was recorded in T_0 control.

Days for first flowering and number of flowers

The minimum days taken for first flowering 55.5 was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) followed by 56.08 days with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and maximum days were taken for first flowering 63.75 was recorded in T_0 control. The maximum number of flowers 28.75 was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) followed by 28.42 with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and minimum number of flowers per plant 18.83 was recorded in T_0 control.

Days for first fruiting and number of flowers

The minimum days taken for first fruiting 62.08 was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) followed by 62.83 days with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and maximum days were taken for first fruiting 70.75 was recorded in T_0 control. The maximum number of fruits 21.83 was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) followed by 20.58 with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and minimum number of fruits per plant 11.50 was recorded in T_0 control.

Table 1. Mean performance of growth parameters in Strawberry

Sl. NO.	Treatments	Plant height (cm)			Number of leaves			Plant spread	Days for flowering	Number of flowers	Days for fruiting	Number of flowers	Fruit length	Fruit width
		30	60	90	30	60	90							
1	**T_0**	**7.16**	**11.66**	**14.33**	**6.58**	**10.2**	**15.1**	**19.16**	**63.75**	**18.83**	**70.75**	**11.50**	**3.33**	**2.63**
2	**T_1**	8.25	13.16	16.91	7.75	12.2	16.9	22.91	58.41	26.00	66.08	18.17	3.63	3.46
3	**T_2**	9.6	14	17.91	8.41	12.8	18.6	23.66	57.41	22.33	65	15.17	4.06	3.76
4	**T_3**	10.33	14.83	20.83	9.33	14.1	20.3	25.16	56.08	28.42	62.83	20.58	4.66	4.06
5	**T_4**	7.83	12.83	16.25	8.25	12.4	17.6	23.16	58	21.42	65.58	13.92	3.8	3.63
6	**T_5**	9.33	13.66	17.58	7.16	11.1	16.1	21.91	61.91	24.83	69	16.83	3.43	3.03
7	T_6	7.66	12.25	15.56	7.41	11.8	16.6	22.25	60	20.17	67.16	12.08	3.56	3.26
8	**T_7**	8.83	13.25	17.33	7.83	10.6	15.8	21.16	62.66	23.50	69.66	15.75	3.36	2.86
9	**T_8**	**10.92**	**15.75**	**21.66**	**9.5**	**14.5**	**21.3**	**26.33**	**55.5**	**28.75**	**62.08**	**21.83**	**4.9**	**4.16**
9	**T_9**	9.91	14.58	18.41	8.83	13.3	18.9	24.25	56.58	27.67	64.25	19.00	4.2	3.9
F Test		S	S	S	S	S	S	S	S	S	S	S	S	S
S.Ed		3.66	4.96	5.78	1.89	3.6	4.98	5.27	5.56	1.64	6.99	1.68	0.675	0.665
C.V		17.3	15.54	13.9	10.39	12.5	12	9.75	4.011	8.31	4.49	8.23	7.373	8.13

Table 2. Mean performance of Yield and quality parameters in Strawberry

Sl. NO.	TTreatments	Average fruit weight	Yield per plant	Yield per plot	Yield per hectare	TSS	Acidity	Ascorbic acid
1	**T_0**	**13.17**	**147.43**	**1059.00**	**5.86**	**6.633**	**0.742**	**53.75**
2	**T_1**	14.67	248.27	1832.51	9.65	8.03	0.70	57.86
3	**T_2**	15.92	241.43	1467.70	11.41	8.73	0.673	59.34
4	**T_3**	17.13	345.63	2442.64	12.36	9.67	0.648	61.70
5	**T_4**	16.88	229.10	1554.44	11.18	8.56	0.699	58.84
6	**T_5**	16.40	273.71	2015.79	8.27	7.36	0.725	55.35
7	T_6	16.78	200.27	1320.97	9.68	7.67	0.71	55.96
8	**T_7**	16.90	259.59	2057.51	8.39	7.06	0.742	54.81
9	**T_8**	**17.53**	**381.44**	**2701.34**	**13.49**	**10.07**	**0.631**	**63.65**
10	**T_9**	16.53	331.45	2299.91	11.58	9.27	0.656	59.88
F Test		S	S	S	S	S	S	S
SeD		1.56	22.60	97.97	0.63	1.2	4.66	7.001
C.V		11.76	10.41	6.40	7.58	6.16	9.81	5.128

Table 3. Gross returns, net returns and B:C ratio

Treatments	treatments combinations	Total cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C Ratio
T_0	Control	477500	885133	407633	1.853682
T_1	GA_3 @ 25 ppm/l + Triacontanol @ 5.25ppm/l	481617	1446785	965168	3.004016
T_2	GA_3 @ 75 ppm/l + NAA @ 40ppm/l	487962	1712150	1224188	3.508777
T_3	GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l	488640	1752450	1263810	3.586383
T_4	NAA @ 20 ppm/l + GA_3 @ 75 ppm/l	486762	1676285	1189523	3.443747
T_5	NAA @ 40 ppm/l + Traicontanol @ 3.25 ppm/l	480680	1240620	759940	2.580969
T_6	NAA @ 60 ppm/l + GA_3 @ 25 ppm/l	483787	1451350	967563	2.999977
T_7	Triacontanol @ 1.25 ppm/l + NAA @ 20 ppm/l	480290	1258440	778150	2.620167
T_8	Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l	489680	2023500	1533820	4.13229
T_9	Triacontanol @ 5.25 @ ppm/l + NAA @ 60 ppm/l	482530	1736800	1254270	3.599362

Fruit length and fruit width

The maximum length of fruit 4.9 cm was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) followed by 4.66cm with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and minimum fruit length 3.33cm was recorded in T_0 control.

The maximum width of fruit 4.16 cm was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) followed by 4.06cm with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and minimum fruit width 2.63cm was recorded in T_0 control. Similar findings were observed by Jain and Dashora [5], Kumar et al., [6] on triaconatol, Choudary et al., [7] on triaconatol, Saima et al., [1], Vishal et al., [3], Tiwari et al., [8].

B. Yield parameters

Average fruit weight

The average fruit weight of strawberry as influenced by growth regulators are found significantly maximum fruit weight 17.53g was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) and followed 17.13g with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and minimum fruit weight 13.17g was recorded in T_0 control.

Yield per plant, plot, hectare

The maximum yield per plant 381.44 g/plant was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) and followed by 345.63 g/plant with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and minimum yield per plant 147.43 g/plant was recorded in T_0 control. The maximum yield per plot 2701.34 g/plot was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) and followed by 2442.64 g/plot with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and minimum yield per plot 1059.00 g/plant was recorded in T_0 control. The maximum yield per hectare 13.49 t/ha was recorded in the treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) and followed by 12.36 t/ha with T_3 (GA_3 @ 100ppm/l + Triacontanol @ 1.25 ppm/l) and minimum yield per hectare 5.86 t/ha was recorded in T_0 control.

Similar results were observed by Kumar et al., [6], Khirmani et al., [9], Khunte et al., [10], Sarita Paikra et al., [11].

C. Quality parameters

TSS content, Acidity, Ascorbic acid

The highest TSS content 10.07(^{0}Brix) was noticed in T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) and minimum TSS content 6.63(^{0}Brix) was observed in T_0 control. The maximum acidity 0.63 was recoreded in T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) and minimum acidity 0.74 was reported in T_0 control. the highest ascorbic acid 63.65 was recorded in T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) followed by 61.70 in T_3 (GA_3 @ 100 ppm/l + Triacontanol @ 1.25 ppm/l) and minimum ascorbic acid 53.75 was observed in T_0 control.

Similar findings were agreed with the work of Singh et al., [12], Kumar et al., (2008), Singh et al., (2010), Kumar et al., (2013), Suvalaxmi et al.,(2016).

Cost of cultivation, Gross retirns, Net returns.

The maximum cost of cultivation (489680) Rs/ha was recorded under treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) and minimum cost of cultivation(477500) Rs/ha was recorded under treatment Control. The maximum gross returns(2023500) Rs/ha was recorded under treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) and minimum gross returns 885133 Rs/ha was recorded under treatment control. The maximum net returns (1533820) Rs/ha was recorded under treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) and minimum net returns (407633) Rs/ha was recorded under treatment control. The maximum benefit cost ratio (4.1) was recorded under treatment T_8 (Triacontanol @ 3.25 ppm/l + GA_3 @ 100 ppm/l) and minimum benefit cost (1.85) was recorded under treatment control Similar findings were recorded by Bhosale [13], Verma [14] on GA_3.

4. CONCLUSION

Foliar application of growth regulators on strawberry plants, significantly increased yield and quality in field conditions. T_8- (Triacontanol

@ 3.25 ppm/l + GA_3 @ 100 ppm/l) gave positive results on both yield and highest economic returns among all treatments used and followed by T_3 (GA_3 @100ppm + Triacontanol @ 1.25 ppm/l). T_0 control showed minimum performance in comparison to others Combination with GA_3 and Triacontanol gave best results to enhance plant height, early flowering and good fruit yield. Plant growth regulators also promotes early maturity rapid fruit growth and development..Therefore, it is concluded as organic, eco-friendly and economic in use.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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