Effect of GA_3 and NAA on yield and benefit: cost ratio of strawberry (*Fragaria x ananassa* Duch.) cv. Chandler under the open condition of Manipur

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Summary

The present experiment was conducted at the experimental field of the College of Agriculture, Central Agricultural University, Imphal, Manipur during the session 2021-22. It was Entitled as the effect of GA_3 and NAA on yield and benefit: cost ratio of strawberry (*Fragaria x ananassa* Duch.) cv. Chandler under open conditions of Manipur. The experiments plot was laid out in Randomized Block Design with three replication and nine treatments with the combination of GA_3 and NAA *viz*., T_1 (Control), T_2 (GA_3 25 ppm), T_3 (GA_3 50 ppm), T_4 (GA_3 75 ppm), T_5 (GA_3 100 ppm), T_6 (NAA 25 ppm), T_7 (NAA 50 ppm), T_8 (NAA 75 ppm) and T_9 (NAA 100 ppm), the treatment GA_3 @ 75 ppm was found maximum concerning several fruits, fruit length, fruit diameter, fruit volume, specific gravity, harvesting duration, yield and B: C ratio as compared with other treatments and the minimum was recorded in control. Hence, it is concluded that treatment T_4 (GA_3 75 ppm) positively impacts yield and benefit: cost ratio of strawberry cv. Chandler under open conditions of Manipur.

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INTRODUCTION

Strawberry (*Fragaria x ananassa* Duch.) is a member of the Rosaceae family. It has resulted from the hybridisation of two American diploids, *Fragaria chilonensis* and *Fragaria virginiana*. Strawberry is among the most delicious, nutritious, soft and attractive berries fruit crops.[7, 8] It is a monoecious, short-day, fast-growing stoloniferous herb grown under a wide range of agro-climatic conditions, cultivated annually in sub-tropical climates and as a perennial in temperate climates. Strawberry plants perform well under protected cultivation rather than open practices. The fleshy bright red berries are the economic part morphologically an etaerio of achenes. Strawberry fruits grow in a single sigmoid pattern with an exponential increase in size in the latter stages, which was related to softening. Strawberry plants thrive at temperatures ranging from 22 to 23 °C during the day and 7 to 13°C at night. Frost and winter damage cause berries to be severely reduced. Plants thrive in a pH range of 5 to 6.5 in sandy loam soil as root spreads 15 to 20 cm. in the soil surface. The total world production of Strawberries is 8,885,028 tonnes with a cultivated area over 396,401 hectares.[1] In India, strawberry is grown with a production of 9000 MT in an area of 3000 ha.[2] The cultivation of strawberries in the Northeast Region of India is not always executed commercially because of a lack of knowledge about its cultivation. Strawberry plants have very specific requirements for soil, climate, fertilizers, mulch and different farming strategies. The North-eastern states have the capacity to cultivate strawberries and become the country's primary strawberry producer. The North-eastern states offer many opportunities for successful strawberry farming due to their mild and pleasant climatic conditions. In the Northeast region of India, strawberry cv. Chandler is one of the most common and suitable grown varieties in this region. Its berry is conical to long and flat in shape, shiny and glossy skin with attractive colour, self-fertile and highly resistant to all viral diseases.[18, 10] However, strawberry growers in this region are lacking good agricultural practices (GAPs) for a sustainable yield of this newly introduced fruit crop. Therefore, the present investigation explored the application of plant growth regulators *viz*. NAA and GA_3 for sustainable yield for strawberry cv. Chandler is under open field conditions in Manipur.

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Materials and Methods

The present experiment entitled "Effect of Plant Growth Regulators GA_3 and NAA on Vegetative Growth of Strawberry (*Fragaria x ananassa* Duch.) cv. Chandler Under Open Condition of Manipur" was conducted at the experimental field of College of Agriculture, Central Agricultural University, Imphal, Manipur during the session 2021-22. The experimental site is located at 24.8074°N 93.9384°E in extreme eastern India, with an average elevation of 786 meters. The field was properly prepared by repeated ploughing with the help of a power tiller, and a well-rotted farm was integrated into the soil and applied recommended doses of fertilizers. During the third week of September 2020, disease-free and healthy runners of strawberry cv. Chandler was planted to the raised beds at 30 cm x 30 cm spacing. The experiment was laid out in Randomized Block Design with nine treatments, and each was replicated thrice. The treatments consisted of nine different concentrations of GA_3 and NAA *viz*., T_1 (Control), T_2 (GA3 25 ppm), T_3 (GA3 50 ppm) T_4 (GA3 75 ppm), T_5 (GA3 100 ppm), T_6 (NAA 25 ppm), T_7 (NAA 50 ppm), T_8 (NAA 75 ppm), T_9 (NAA 100 ppm). The various observations were recorded from five selected plants of each replication in terms of the number of fruits, fruit length, fruit diameter, fruit weight, fruit volume, duration of harvesting, yield per plant, yield quintal per hectare, B: C ratio while the harvesting index and specific gravity determined by the following method.

Harvest Index

Harvest index was calculated using the following formula given by Donald (1962)[5]:

$$Harvesting\ index = \frac{Economic\ yield\ (fruit\ weight\ in\ kg.)}{Total\ biomass\ production\ (total\ fresh\ weight\ per\ plant\ in\ kg.)}$$

Specific gravity (g/cm³)

Firstly, the weight of selected fruits was taken and placed in a water-filled measuring cylinder and displaced water. The recorded weight of the fruit divided by the displaced water of the fruit is calculated has a specific gravity of fruit.[13]

$$Specific\ gravity\ \left(\frac{g}{cm^3}\right) = \frac{weight\ of\ the\ fruit\ (g.)}{volume\ of\ water\ displaced\ (cm^3)}$$

Results and Discussion

Yield parameters

The finding on the number of fruits per plant in different treatment combinations has shown significant differences as presented in Table 1. The data show that plants treated with T_4 (GA_3 75 ppm) recorded a maximum number of fruits (25.20), followed by (24.53) treated with T_5 (GA_3 100 ppm), while the minimum number (16.47) of fruits recorded in untreated plants. The T_4 (GA_3 100 ppm) produced the maximum fruits per plant (25.20), whereas the control produced the lowest (16.47). By accelerating the translocation and mobilization of stored photosynthates or metabolites from source to sink, GA_3 and NAA application enhanced the number of fruits per plant Jamal *et al.* (2012)[9], Saima *et al.* (2014)[21] and Sekhar *et al.*, (2016)[22] also similarly found outcomes in strawberry.

Table 1: Effect of GA_3 and NAA on the number of fruits, fruit weight, fruit volume and fruit size of strawberry cv. Chandler

Treatments	No. of fruits per plant	Fruit weight (g)	Fruit volume (cc)	Fruit size (cm)	
				Fruit length (cm)	Fruit diameter (cm)
Control	16.47	8.39	8.85	3.04	1.88
GA_3-25ppm	23.73	11.99	12.24	4.57	2.23
GA_3 -50 ppm	24.07	11.93	12.12	4.58	2.48
GA_3 -75 ppm	25.2	12.41	13.24	4.73	2.62
GA_3 -100 ppm	24.53	12.04	13.07	4.67	2.58
NAA -25ppm	23	12.31	13.11	4.63	2.59
NAA -50 ppm	22.13	12.19	12.81	4.51	2.27
NAA -75 ppm	21.73	11.52	11.69	4.47	2.11
NAA -100 ppm	21.33	11.09	11.35	4.17	2.19
S.E.d(±)	0.36	0.48	0.53	0.12	0.1
C.D. (P=0.05)	0.77	1.03	1.12	0.26	0.21

S.E.d(±)- Standard Error of Difference, C.D. (P=0.05) critical difference at 5% significance level.

The finding on the fruit length in different treatment combinations has shown significant differences as presented in Table 1. The data show that plants treated with T_4 (GA_3 75 ppm) found the largest fruit length (4.73 cm), followed by (4.67 cm) treated with T_5 (GA_3 100 ppm), while the smallest fruit length (3.04 cm) was measured in the untreated plant. The highest fruit length (4.73 cm) was attained under T_4 (GA_3 75 ppm) and the minimum (3.04 cm) was recorded under control. The increase in fruit length may be attributed to higher carbohydrates and GA_3 might have encouraged cell division and cell expansion resulting in maximum fruit length. Similar findings were reinforced by the results of Tripathi and Shukla (2010)[31], Thakur *et al.,* (2015)[28] and Yadav *et al.* (2017)[32] on strawberries.

The results on the fruit diameter in different treatment combinations is shows significant differences presented in Table 1. The data show that plants treated with T_4 (GA_3 75 ppm) found a maximum fruit diameter (2.62 cm), followed by (2.59 cm) treated with T_6 (NAA 25 ppm), while the minimum fruit diameter (1.88 cm) was measured in untreated plants. The treatment T_4 (GA_3 75 ppm) reported a maximum diameter of fruit (4.73 cm) whereas, the lowest fruit diameter (1.88 cm) was recorded under control. The rise in fruit size and weight during the current investigation can be related to the higher photosynthetic capacity of plants treated with GA_3, which encouraged and enhanced the accumulation of total solids and might be a smaller number of fruits. Similar findings were reported by Tripathi and Shukla (2006)[29] and Yadav *et al.* (2017)[32] in strawberries.

The investigation of the fruit weight (g) in different treatment combinations showed significant differences as presented in Table 1. The data show that plants treated with T_4 (GA_3 75 ppm) found maximum fruit weight (12.41 g), followed by (12.31g) treated with T_6 (NAA 100 ppm) while the minimum fruit weight (8.39 g) was reported in control. The maximum fruit weight may have occurred because of exogenous GA_3 treatment, which increased cell elongation or expansion and speed up fruit development and ultimate size. All vegetative components' growth has been accelerated by GA_3, and as a result, these plants have generated more food material for fruit development and, in the case of the current study, fruits with the highest weight. The results of the current study are very consistent with Uddin *et al.* (2012)[9], Thakur *et al.* (2015)[28] and Kaur and Mirza (2018)[11].

The significant information on fruit volume as influenced by various treatments is shown in Table 1. The data show that plants treated with T_4 (GA_3 75 ppm) found maximum fruit volume (13.24 cc), followed by (13.11 cc) treated with T_6 (NAA 25 ppm), while the minimum fruit volume (8.85 cc) was reported in control. The physiological foundation for the rise in fruit volume seems to be related to a faster rate of growth via cell division and cell elongation. Plant growth regulators may have a role in the quick absorption and mobilization of photo assimilates to fruits. Adding T_4 (GA_3 75 ppm) greatly boosted the average volume of fruit. Tripathi and Shukla (2010)[31], Saima *et al.* (2014)[21] and Tanushree *et al.* (2019)[27] reported similar findings on the fruit volume of strawberries.

The significant information on specific gravity (g/cm³) influenced by various treatments is shown in Table 2. The data shows that plants treated with different growth regulators had maximum specific gravity (0.98 g/cm³), followed by (0.95 g/cm³), while the minimum specific gravity (0.92 g/cm³) was reported.

Table 2: Effect of GA_3 and NAA on harvest duration, harvest index, specific gravity and yield of strawberry cv. Chandler

Treatments	Duration of harvest (DAPs)	Harvest index	Specific gravity (g/cm3)	Yield	
				Yield/plant (g)	Yield q/ha
Control	58.49	1.98	0.95	137.97	153.31
GA_3-25ppm	64.14	2.81	0.98	284.3	315.88
GA_3 -50 ppm	67.93	2.67	0.98	286.94	318.82
GA_3 -75 ppm	71.08	3.21	0.94	312.44	347.15
GA_3 -100 ppm	69.64	3.23	0.92	295.28	328.09
NAA -25ppm	67.09	2.99	0.94	283.29	314.76
NAA -50 ppm	66.24	3.17	0.95	269.71	299.67
NAA -75 ppm	64.6	3.12	0.98	251.02	278.92
NAA -100 ppm	64.44	3.66	0.98	236.52	262.8
S. Ed (±)	0.86	0.13	0.03	11.92	13.24
C.D. (P=0.05)	1.83	0.27	0.05	25.26	28.07

S.E.d(±) Standard Error of Difference, C.D. (P=0.05) critical difference at 5% significance level.

The maximum specific gravity (0.98 g/cm³) was found whereas, the lowest (0.98 g/cm³) The rise in fruit size and weight during the current investigation can be related to the higher photosynthetic capacity of plants treated with GA_3, which is increasing the sink strength and total solids resulting in an increase in specific gravity. This result is similar to Kumar *et al.* (2011)[14]. Further similar findings were also achieved by Saima *et al.* (2014)[21], Khunte *et al*, (2014)[12] in strawberries.

The significant information on the duration of harvesting of various treatment combinations is presented in Table 2. The data shows that plants treated with T_4 (GA_3 75 ppm) found a maximum duration of harvesting (71.08 days) followed by (69.64 days) treated with T_5 (GA_3 100 ppm), while the minimum duration of harvesting (58.49 days) was reported in control. The maximum harvesting length (71.08 days) was observed from T_4 (GA_3 75 ppm) treated plants, followed by (69.64 days) with T_5 (GA_3 100 ppm), while the least harvesting period (58.49 days) was reported in control. Similar findings were obtained by Singh and Singh (2009)[24], Kumar and Tripathi (2009)[16] and Yadav *et al.* (2017)[32], who increased the duration of harvesting (earliness) by nearly one month, hence extending the harvesting period. The potential of growth hormones to stimulate development and lengthen harvesting duration may be responsible for the increase in harvesting duration seen in the current study.

Data on yield per plant as influenced by various treatment combinations are reported in Table 2. The statistics clearly show that the plants treated with T_4 (GA_3 75 ppm) produced the highest yield (312 g) per plant, which was statistically significant, followed by (295.28 g) in T_5 (GA_3 100 ppm). The untreated plant produced the lowest yield per plant (137.97 g). GA3-treated plants may have greater vegetative growth, which promotes better fruit set and fruit weight, which may account for the rise in fruit production per plant. Throughout the duration of the life cycle, its vegetative development determines the yield characteristics of the sink capability of the crop. A crop's ability to absorb more nutrients is increased by vigorous vegetative growth. Large leaves and rapid photosynthesis may have produced more metabolites, accounting for the larger yield. The results of Anwar *et al*. (1990)[3], Sharma and Singh (1990)[23], Tripathi and Shukla (2007)[30], Singh and Tripathi (2010)[26], Rakesh *et al.* (2014)[20], and Saima *et al*. (2014)[21] in the strawberry crop are consistent with this conclusion.

Data on yield (q/ha) as influenced by various treatment combinations are reported in Table 2. The findings clearly show that the plants treated with T_4 (GA_3 75 ppm) produced the highest yield (347.15 q/ha), which was statistically significant, followed by (328.09 q/ha) treated with T_5 (GA_3 100 ppm). The untreated plant produced the lowest yield (153.31 q/ha). Plants treated with T_4 (GA_3 75 ppm) produced the highest yield (347.15 q/ha), while untreated plants produced the lowest yield (153.31 q/ha). The enhanced output might be attributed to greater flowering and fruit sets, as well as improved fruit weight and size. Higher diversion of photosynthates to sink (berries), resulting in increased fruit yield. Additionally, GA_3 boosted the nutrient supply and other chemicals to the fruits, which is essential for their optimal growth and development, resulting in increased fruit size and, ultimately, high production. These findings are similar to Kumar *et al.* (2012a)[13], Rajbhar *et al.* (2014)[19], Sarita Paikra (2018)[17] in strawberry.

The significant information on the harvest index influenced by various treatments is shown in Table 2. The data shows that plants treated with T_9 (NAA 100 ppm) found a maximum harvest index (3.66), followed by treatment with T_5 (GA_3 100 ppm) (3.23), while the minimum harvest index (1.98) was reported in the control. The plant growth regulators are promoting vigorous vegetative and reproductive growth which account for the rise in fruit production and biological yield. The harvest index is found maximum in plants treated with different growth regulators while the minimum harvest index was found in control. Throughout the duration of the life cycle of the plant, its vegetative development determines the yield characteristics of the sink capability of the crop. Present findings are similar to the work of Galletta *at al.* (1995)[6] in strawberries, Yazdpour *et al.* (2012)[35], Singh *et al.* (2012)[25] in coriander and Anusuya et al. (2018)[4] in mango.

Benefit: Cost ratio

The finding on the Benefit: Cost ratio in different treatment combinations showed significant differences presented in Table 3. The data shows that plants treated with T_4 (GA_3 75 ppm) found a maximum Benefit: Cost Ratio (3.73: 1), followed by (3.45:1) Those treated with T_5 (GA_3 100 ppm), while the minimum Benefit: Cost Ratio (1.12:1) was reported in control. Strawberry cultivation costs include the cost of planting material, manure, field preparation, mulch material and labour. The treatment T_4 (GA_3 75 ppm) had the highest benefit: cost ratio (3.73: 1) T_4 (GA_3 75 ppm) was recognized as inexpensive and beneficial for strawberry cultivation in Imphal (Manipur) region. The results of the current study are very consistent with the findings Yadav *et al.* (2010)[33], Kumar *et al.* (2012b)[15], Paikra (2018)[17], Yashwanti et al. (2016)[34] and Tanushree *et al.* (2019)[27].

Table 3: Effect of GA_3 and NAA on the economics of strawberry cv. Chandler

Treatments	Cost of cultivation (Rs. /ha.)	Gross return (Rs. /ha.)	Net return (Rs. /ha.)	Benefit: Cost Ratio
Control	2022179	4292541	2270361	1.12
GA_3-25ppm	2035999	8844731	6808731	3.34
GA_3 -50 ppm	2045499	8926993	6881493	3.36
GA_3 -75 ppm	2054999	9720284	7665284	3.73
GA_3 -100 ppm	2064499	9186459	7121960	3.45
NAA -25ppm	2026869	8813418	6786548	3.35
NAA -50 ppm	2027239	8390891	6363651	3.14
NAA -75 ppm	2027609	7809628	5782018	2.85
NAA -100 ppm	2027979	7358476	5330496	2.63

Conclusion

The results clearly show that plants treated with GA_3 75 ppm found a maximum number of fruits (25.20), fruit length (4.73 cm.), fruit diameter (2.62 cm.), fruit weight (12.41 g), Fruit volume (13.24 cc), the longest duration of harvesting (71.08 days), yield (312 g) per plant, yield (347.15 q/ha) and Benefit: Cost Ratio (3.73:) while the minimum recorded in untreated plants. Thus, the study of present findings can be concluded that how different growth regulators have a positive impact on strawberry cv. Chandler with respect to yield and benefit: cost ratio. The strawberry crop produced the most yield, and benfit: cost returns with the GA_3 75 ppm under the Manipur region.

Declaration of interests

The authors have no conflict of interest to declare.

Data sharing

All relevant data are within the manuscript.

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