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FIELD ASSESSMENT OF GROWTH REGULATORS ON YIELD AND ECONOMICS OF STRAWBERRY: A SOUTH GUJARAT PERSPECTIVE

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ABSTRACT

Strawberry fruit production needs better and more efficient control of all agricultural inputs used in its cultivation. Otherwise, a sufficient return is difficult to obtain. As a result, some growth-regulating compounds can be used at specific periods of growth to increase yield potential. The experiment was laid out in Randomized Block Design (RBD) with nine treatments *viz.*, T_1 = 50 mg l^{-1} NAA, T_2 = 75 mg l^{-1} NAA, T_3=100 mg l^{-1} NAA, T_4= 125 mg l^{-1} NAA, T_5=50 mg l^{-1} GA_3, T_6 = 75 mg l^{-1} GA_3, T_7 = 100 mg l^{-1} GA_3, T_8 = 125 mg l^{-1} GA_3 and T_9 = No spray (Control), which were replicated thrice. Among different application of plant growth regulator, 100 mg l^{-1} GA_3 performed significantly superior over other treatment with respect to percentage of marketable fruit (85.73%), marketable fruit yield (108.95 q/ha), total yield (117.15 q/ha), net income (10,79,717¹ /ha) and BCR (2.42) with minimum percentage of non-marketable fruit (14.27%) and non-marketable fruit yield (8.19 q/ha), whereas highest fruit set (61.47%) was observed in 125 mg l^{-1} NAA.

***Key words*:** Growth-regulating compounds, economics, PGR, strawberry

Introduction

The strawberry (*Fragaria* × *ananassa* Duch.) is a significant perennial fruit crop in the Rosaceae family. *Fragaria chiloensis* (L.) Miller and *Fragaria virginiana* Miller are two dioecious octaploid species which used in hybridized to become the modern strawberry (Hummer and Hancock, 2009). The resultant hybrid is also become octaploid (2n = 56) with basic chromosome number (×) seven. Strawberries are extensively grown in temperate to subtropical climates. After development of cultivated strawberry in France, it was spread to around the globe. It was introduced during the early 16^{th} century in India (Sharma and Sharma, 2004). In India, strawberry is a widely cultivated in Himachal Pradesh, Uttar Pradesh, Kashmir Valley, Maharashtra and Karnataka (Pramanick *et al.*, 2013). Presently, it is cultivated in an area about 2620 ha with a total production of 20,010 MT in India (Anon., 2023-24).

The strawberry *cv*. "Winter Dawn" is a relatively new cultivar developed by Florida Foundation Seed Producers, Inc., Greenwood, Florida (US). They have been reported to perform well under poly house as well as open field conditions in India (Kumar *et al.*, 2016). The primary fruits of this cultivar are found to be conic-wedge shaped, whereas the secondary and tertiary fruits are conic-oval shaped. It has the ability to produce 3 large fruits on a relatively small plant. The fruiting season begins from November and ends in the last week of February (Santos *et al.*, 2007). It is also moderately resistance to crown rot, botrytis and anthracnose fruit rot.

Strawberry give a higher returns as compared to other cultivated fruit crops. Therefore, adoption of strawberry cultivation is suggested in different parts of India not only to increase the income as well as to generate the employment opportunities (Kumar *et al.*, 2016). It is considered that the adoption of strawberry farming would be able to double the farmer's income in

North Eastern India (Hossain *et al.*, 2017). Dang district (Gujarat) has found to be congenial for the cultivation of the strawberry.

Strawberry fruit production requires some special techniques to obtain the sufficient return. As a result, some growth-regulating compounds can be used at specific periods of growth to increase revenue. Plant growth regulators can control several parts of the plant system, including growth, blooming, fruiting, ripening and yield. Scientific research also suggests that the strawberry plant responded positively to growth regulator treatment (Hazarika *et al.*, 2017).

Among the plant growth regulators, Naphthalene Acetic Acid (NAA) and Gibberellic Acid (GA_3) have been widely used in modern agricultural system. The role of these plant growth regulators has been investigated in several fruits. It is reported that NAA and gibberellins are essential during fruit set and early development stages of strawberry fruit (Kang *et al.*, 2013 & Vishal *et al.*, 2023). These plant growth regulators stimulate growth of fruit tissues and even determine the fruit size (Ozga *et al.*, 2003). It is well documented that production of dry matter and fruit quality in terms of total sugar and ascorbic acid content can be improved by exogenous application of Naphthalene Acetic Acid (NAA). Naphthalene acetic acid has the property to delay the ripening and develop excellent colour of skin in strawberry fruit due to higher accumulation of anthocyanin pigments (Villrreal *et al.*, 2009).

Among the gibberellins, GA_3 is the most commonly used to the fruit plants. Exogenous application of gibberellic acid is reported to promote the length of petiole, elongate the internodes and increase the runner formation in strawberry (Guttridge and Thompson, 1959). Further, GA_3 inhibited the ripening of strawberry fruits by decrease the rate of respiration and delay the synthesis of anthocyanin and degradation of chlorophylls (Martínez *et al.*, 1994).

Material and Methods

The present investigation entitled "Field assessment of growth regulators on yield and economics of strawberry: A South Gujarat perspective" was conducted during 2017-18 at Rambhas Farm, Hill Millet Research Station, Navsari Agricultural University, Waghai, Gujarat, India. The experiment was laid out in Randomized Block Design (RBD) with nine treatments *viz.*, T_1= 50mg l^{-1} NAA, T_2= 75mg l^{-1} NAA, T_3= 100 mg l^{-1} NAA, T_4=125mg l^{-1} NAA, T_5= 50mg l^{-1} GA_3, T_6= 75mg l^{-1} GA_3, T_7=100mg l^{-1} GA_3, T_8= 125 mg l^{-1} GA_3 and T_9= Nospray (Control) which were replicated thrice.

The experimental site was sandy loam and neutral in reaction with pH 6.7. The 313.6 kg ha^{-1} available N, 60.7 kg ha^{-1} available P, 230.8 kg ha^{-1} available K and 1.20 % organic C in experimental soil. The recommended dose of fertilizers i.e., FYM 10^t ha^{-1} and 120:80:100kg N P K ha^{-1} was applied. Healthy, well developed, almost uniform, pest and disease-free runner plantlets of strawberry cv. Winter Dawn were planted at second week of October at a spacing of 60×30 cm under paddy straw mulching. Each experimental bed (3.0×1.8m) comprised of 30 plants with 12 plants in a net plot area (1.8×1.2 m). Foliar spraying of plant growth regulators (NAA and GA_3) was carried out at 30 and 60 days after planting. Following observations were taken for the different treatments.

Fruit set (%)

The fruit set was determined by observing the petal fall stage in the flowers of previously tagged five plants in the net plot area under each replication and the percentage was calculated by dividing the successful fruits with total number of flowers and multiplied by 100 and then average was worked out.

$$Fruit\ set\ (\%) = \frac{Number\ of\ fruits\ per\ plant}{Number\ of\ flowers\ per\ plant} \times 100$$

Marketable yield (q/ha)

The weight of harvested marketable fruits from each net plot (from first picking to the end of experiment) under each treatment was recorded with digital weighing balance and then the mean weight was expressed in kilogram. The marketable yield per plot was converted in hectare and expressed in quintal to obtain marketable yield per hectare.

Non-marketable yield (q/ha)

The weight of harvested non-marketable fruits from each net plot (from first picking to the end of experiment) under each treatment was recorded with digital weighing balance and then the mean weight was expressed in gram. The non-marketable yield per plot was converted in hectare and expressed in quintal to obtain non-marketable yield per hectare.

Total yield (q/ha)

The total weight of harvested marketable and non-marketable fruits from each net plot (from first picking to the end of experiment) under each treatment was recorded with digital weighing balance and then the mean weight was expressed in kilogram.

Misshapen fruits (%)

The number of misshapen fruits (Deformed fruits having weight <10.0 g) from the lot of non-marketable fruits were recorded during each picking from the net plot area under each treatment and summed up and then percentage was worked out on the basis total number of fruits.

Table 1: Field assessment of growth regulators on fruit set, markable & non-markatable fruit of strawberry.

Treatment	Fruit set (%)	Marketable fruits (%)	Non-Marketable fruits (%)	Misshapen fruits (%)	Disease infected Fruits (%)
T_1:NAA@ 50mg l^{-1}	59.65 (50.55)*	77.79 (61.89)	22.21 (28.08)	19.32 (26.05)	2.88 (9.71)
T_2:NAA@ 75mg l^{-1}	60.46 (51.03)	80.64 (63.87)	19.36 (26.09)	16.93 (24.29)	2.43 (8.94)
T_3:NAA@ 100mg l^{-1}	61.28 (51.51)	84.92 (67.13)	15.08 (22.83)	13.16 (21.25)	1.92 (7.89)
T_4:NAA@ 125mg l^{-1}	61.47 (51.66)	84.06 (66.48)	15.94 (23.48)	13.90 (21.85)	2.04 (8.18)
T_5:GA_3@ 50mg l^{-1}	59.72 (50.58)	80.53 (63.94)	19.47 (26.03)	17.85 (24.84)	1.62 (7.21)
T6:GA3@ 75mg l^{-1}	59.66 (50.57)	82.18 (65.02)	17.82 (24.95)	16.29 (23.77)	1.53 (7.01)
T_7:GA_3@ 100mg l^{-1}	59.89 (50.69)	85.73 (67.88)	14.27 (22.09)	13.20 (21.18)	1.07 (5.93)
T_8:GA_3@ 125mg l^{-1}	59.63 (50.61)	81.73 (64.69)	18.27 (25.28)	17.17 (24.46)	1.09 (5.99)
T_9: Control (No spray)	59.61 (50.53)	76.16 (60.76)	23.84 (29.21)	20.57 (26.96)	3.28 (10.38)
SE m ±	1.68	1.12	1.12	1.12	0.49
CD at 5 %	NS	3.34	3.34	3.34	1.48

*Figures in parentheses are the arc sine transformed values

Disease infected fruits (%)

The number of disease infected fruits from the lot of non- marketable fruits were recorded during each picking from the net plot area under each treatment and summed up and then percentage was worked out on the basis total number of fruits.

Economics

Economics was calculated by considering prevailing market prices for the different inputs and produces. The gross income was calculated on the basis of strawberry fruit yield for each treatment considering the prevailing market price. The cost of cultivation of each treatment was calculated by considering the current rate of all the operation right from the preparation of land to the harvesting. Net income per hectare for each treatment was worked out by the subtracting total cost of cultivation from the gross income of each treatment. For this, benefit cost ratio (BCR) was worked out using the following formula.

$$BCR = \frac{Net\ income\ \square/\text{ha}}{Total\ cost\ of\ cultivation\ \square/\text{ha}}$$

Statistical analysis

The data recorded for all the characters were subjected to the statistical analysis by adopting 'Analysis of Variance' technique as described by Panse and Sukhatme, (1967) for Randomized Block Design.

Result and Discussion

Fruit set (%)

The data on fruit set percentage are mentioned in Table 1 indicates that fruit set percentage of strawberry was not significantly influenced by the spraying of different concentration of plant growth regulators. However, the maximum fruit set (61.47%) was recorded in T_4 (NAA@ 125 mg l^{-1}) which was statistically at par with all the treatments. Whereas the lowest fruit set (59.61%) was recorded in treatment T_9 (control). The present findings are in agreement with those reported by Saima *et al.*, (2014) in strawberry *cv*. Chandler and Yadav *et al.*, (2017) in Winter Dawn cultivar of strawberry.

Percentage of marketable fruits (%)

The data pertaining to the percentage of marketable fruits (%) was presented in Table 1 and graphically presented in fig. 1. The percentage of marketable fruits (85.73%) was recorded the highest in treatment T_7 (GA_3 @ 100mg l^{-1}) which was statistically at par with T_3 (NAA@ 100 mg l^{-1}) and T_4 (NAA @ 125 mg l^{-1}). The lowest value of percentage of marketable fruits (76.16%) was recorded in treatment T_9 (control). It might be due to GA_3 might have affected the auxin metabolism, which might have indirectly helped in the fruit enlargement therefore, production of normal fruits in higher number. The present findings are in agreement with those reported by Sharma and Singh (2009) and Abdullah *et al.*, (2023) in strawberry cv. Chandler.

Percentage of non-marketable fruits (%)

The percentage of non- marketable fruits (%) are mentioned in Table 1. The minimum percentage of non-marketable fruits (14.27%) was recorded in treatment T_7 (GA_3 @ 100 mg l^{-1}) which was found statistically at par with T_3 (NAA @ 100 mg l^{-1}) and T_4 (NAA @ 125 mg l^{-1}). Whereas the maximum percentage of non-marketable fruits (23.84%) was recorded in treatment T_9 (control). It might be due to the fact that control plants did not receive any exogenous application of plant growth regulators treatments. Similar result was reported by Asadi *et al.*, (2013).

Percentage of misshapen fruits (%)

The data on percentage of misshapen fruits are presented in Table 1. The minimum percentage of

Table 2: Field assessment of growth regulators on marketable yield, non- marketable yield and total yield of strawberry.

Treatment	Marketable yield ha^{-1} (q)	Non-marketable Yield ha^{-1} (q)	Total yield (q ha^{-1})
T_1: NAA@ 50mg l^{-1}	69.75	13.09	82.84
T_2: NAA@ 75mg l^{-1}	72.69	11.48	84.17
T_3: NAA@ 100mg l^{-1}	88.73	9.35	98.09
T_4: NAA@ 125mg l^{-1}	93.36	9.14	102.50
T_5: GA_3@ 50mg l^{-1}	71.76	11.88	83.64
T_6: GA_3@ 75mg l^{-1}	87.19	10.00	97.19
T_7: GA_3@ 100mg l^{-1}	108.95	8.19	117.15
T_8: GA_3@ 125mg l^{-1}	94.91	8.60	103.50
T_9: Control (No spray)	64.04	13.69	77.73
SEm±	3.09	0.44	3.02
CD at 5 %	9.28	1.32	9.06

misshapen fruits (13.16%) was recorded in treatment T_3 (NAA@ 100 mg l^{-1}) which was statistically at par with T_7 (GA_3 @ 100 mg l^{-1}) and T_4 (NAA@ 125 mg l^{-1}). Whereas the maximum misshapen fruits percentage (20.57%) was recorded in treatment T_9 (control). It might be due to lack of fertilization of ovary by the pollens that fail the cells to elongate.

Disease infected fruits (%)

The data on misshapen fruits (%) are presented in Table 1. The minimum disease infected fruits (1.07%) were recorded in treatment T_7 (GA_3@ 100 mg l^{-1}) which was at par with T_8 (GA_3@ 125 mg l^{-1}), T_6 (GA_3@ 75 mg l^{-1}), T_3 (NAA @ 100 mg l^{-1}), T_4 (NAA @ 125 mg l^{-1}) and T_2 (NAA @ 75 mg l^{-1}). Whereas, the maximum disease infected fruits percentage (3.28%) was recorded in treatment T_9 (Control). The GA might enhance the disease resistant ability to plants and as a result minimum disease infected fruits recorded in GA_3 treated plants. Similar result was reported in strawberry cv. Festival (Hazarika *et al.*, 2017).

Marketable yield per hectare (q)

The data pertaining to the number of marketable yield per ha was influenced by different plant growth regulators at different concentration and presented in Table 2. The highest marketable yield per ha (108.95 q) was recorded in treatment T_7 (GA_3 @ 100 mg l^{-1}). Whereas, the minimum marketable yield per ha (64.04q) was recorded in treatment T_9 (control). It might be due to GA_3 might have affected the auxin metabolism, which might have indirectly helped in the fruit enlargement therefore, production of normal fruits in higher number. The present findings are in agreement with those reported by Sharma and Singh (2009) and Abdullah *et al.,* (2023) in strawberry *cv*. Chandler.

Non-marketable yield per hectare (q)

The data on non-marketable yield per ha are presented in Table 2. The minimum non-marketable yield per ha (8.19 q) was recorded in treatment T_7 (GA_3 @ 100 mg l^{-1}). The non-marketable yield per ha (13.69 q) was found the maximum in treatment T_9 (control). It might be due to the fact that control plants did not received any exogenous application of plant growth regulators treatments. Similar result was reported by Asadi *et al.*, (2013).

Total yield per hectare (q)

The total yield per ha was significantly affected by the plant growth regulator treatments and presented in Table 2. The maximum yield per ha (117.15 q) was recorded in treatment T_7 (GA_3 @ 100 mg l^{-1}). The total yield per ha (77.73q) was the lowest in treatment T_9 (control). This might be due to the fact of more number of fruits with better size were produced in the plants treated with gibberellic acid. Similar result was also documented in strawberry cv. Chandler (Abdullah *et al.*, 2023; Sharma and Singh, 2009; Kaur *et al.*, 2009 and Rana, 2011) and Douglas (Prasad *et al.*, 2012).

Economics

Economics of strawberry fruits was significantly affected by various plant growth regulators and the data mentioned in Table 3 and graphically presented in Fig. 6. The maximum net realization of Rs.1079717/ ha and maximum BCR (Benefit Cost Ratio) of 2.42 were observed with treatment T_7 (GA_3 @ 100 ppm) over T_9 (control). Similar result was also found in strawberry cv. Chandler (Singh *et al.*, 2022).

Table 3: Field assessment of growth regulators on economics of strawberry.

Treatment	Marketable Fruit yield (q/ha)	Gross return (q/ha)	Cost of production (q/ha)	Net income (q/ha)	B C R
T_1: NAA@ 50mg l^{-1}	69.75	976500	410811	565689	1.38
T_2: NAA@ 75mg l^{-1}	72.69	1017660	413391	604269	1.46
T_3: NAA@ 100mg l^{-1}	88.73	1242220	427435	814785	1.91
T_4: NAA@ 125mg l^{-1}	93.36	1307040	431494	875546	2.03
T_5: GA_3@ 50mg l^{-1}	71.76	1004640	412877	591763	1.43
T_6: GA_3@ 75mg l^{-1}	87.19	1220660	426363	794297	1.86
T_7: GA_3@ 100mg l^{-1}	108.95	1525300	445583	1079717	2.42
T_8: GA_3@ 125mg l^{-1}	94.91	1328740	433434	895306	2.07
T_9: Control (No spray)	64.04	896560	405022	491538	1.21
**Market price of straw berry Rs.140.00 per Kg					

Conclusion

It is concluded from the present study that the foliar application of plant growth regulators (GA_3 and NAA) at 30 and 60 DAS increases yield as well as net returns. NAA @ 125 mg l^{-1} increases the fruit set. Whereas, the foliar spraying of GA_3 @ 100 mg l^{-1} have registered highest percentage of marketable fruits, total yield per ha with minimum percentage of misshapen fruits and disease infected fruit over control treatment.

Author's contribution

Conceptualization and designing of the research work (KDR and BC); Execution of field/ lab experiments and data collection (KDR and BC); Analysis of data and interpretation (KDR and BC); Preparation of manuscript (KDR and PKP).

Declaration

The authors do not have any conflict of interest.

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