Gibberellin, auxin and cytokinin induced changes in vegetative, reproductive and quality attributes of Strawberry (*Fragaria ×ananassa*)

Comment [MV1]: The effect of select plant growth regulators (Gibberellin, auxin and cytokinin) on the morphological growth and physico-chemical characters of Strawberry (*Fragaria ×ananassa*)

Abstract

An experiment was conducted to study the effect of plant growth regulators (gibberellins and auxins) on growth, yield and quality of strawberry during 2019-20under Cuttack, Odisha condition. The experiment was laid out in a randomized block design with ten treatments considering of control (water), GA_3 (50, 75and 100ppm), NAA (50, 75 and 100 ppm) and BAP(50, 75 and 100 ppm) and replicated thrice. Observations were recorded on different vegetative characters like plant height (cm), plant spread (cm), petiole length (cm), leaves per plant, runners per plant, different reproductive characters like days taken to first flower, days taken to fruit bud development, number of flowers per plant, number of fruits per plant and different fruit characters like Length: diameter ratio, Specific gravity, Juice (%), Total soluble solid (°Brix), Ascorbic acid (mg/100g), acidity. The results of investigation revealed that strawberry responds well to application of plant growth regulators. Treatment GA_3 @ 100 ppm gave the best results in terms of vegetative growth and runner production. Different yield attributing characters like numbers of flowers per plant, numbers of fruits per plant, days taken to fruit development and days taken to first fruiting were found to be higher with the application of NAA@ 100 ppm whereas Physico-chemical characteristics with respect to total soluble solid, specific gravity, juice percentage and length to diameter ratio of the fruits were superior in the treatment 75 ppm NAA. But ascorbic acid content and acidity percentage were higher in GA_3 75 ppm.

Comment [MV2]: The method is too long; state the results briefly but complete; also state your objective and the importance of the study

Key words: Fruit quality, Plant growth regulators, Strawberry, Yield

Introduction:

"*Fragaria*" belongs to family Rosaceae, is agenus of the perennial, creeping herbs, found growing in the wild in different climatic zones of the world (CSIR, 1956). The cultivated strawberry (*Fragaria* × *ananassa* Duch.) is a monoecious octaploid hybrid of two largely dioecious octaploid species, *Fragaria chiloensis* Duch. and *Fragaria virginiana* Duch.(Darrow, 1996; Galletta and Bringhurst, 1990; Larson,1994). In *Fragaria*, the receptacle swells into the red-coloured fruit known as a strawberry and over its surface black dots are found, each dot being an individual true fruit. The individual true fruit are termed achenes. Strawberries have significantly high amounts of phenolic flavonoid phyto-chemicals called anthocyanins and ellagic acid. Scientific studies show that consumption of these berries may have potential health benefits against cancer, aging, inflammation and neurological diseases.

Comment [MV3]: Use recent resources

It is amongst the few crops, which give quick and very high returns per unit area on capital investment. $GA_3$and cytokininhas been found to increase the vegetative growth, reproductive behavior of strawberry; Cycocel and NAA improved the yield and quality of strawberry (Thakur *et al*., 1991). Strawberry is a temperate fruit; its production in tropical and subtropical region is drastically low and the market price high. Due to these bottlenecks, the poor people cannot afford it and also farmers seldom go for its cultivation. Keeping this in view, the present studies on strawberry was carried out to find out suitable growth hormone and its concentration for commercial production of good quality strawberry under tropical condition.

Materials and Method:

Comment [MV4]: Elaborate methods; use subheadings

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An experiment was conducted at the Faculty of Agriculture, Sri Sri University,Cuttack, Odisha during 2019-20 to find out the influence of plant growth regulators on growth , yield and quality of strawberry (*Fragaria ×ananassa*) Duch. plant. This region has tropical climate and falls in east and south east coastal zone having humid summers (May–June) and mild winter (December- February) with annual rainfall of about 1542 mm restricted mainly to July–August months. Strawberry runners of almost equal size and vigour were transplanted during evening hours in medium size pots containing the growing media of sand: soil: farm yard manure (1:1:1). Soil was sandy-loam having pH 7.5, which was low in organic carbon (0.42%), medium in available phosphorus and high in potash. All cultural practices were followed uniformly in the experimental pot. Experiment was laid out in randomized block design with ten treatments as following, T_1 -control(Water), T_2 - GA_3@50 ppm, T_3 - GA_3 @75 ppm, T_4 - GA_3@100 ppm, T_5 - NAA @50 ppm, T_6 – NAA@ 75 ppm, T_7 – NAA@100ppm, T_8 - BAP @50 ppm, T_9 - BAP @75 ppm, T_{10} - BAP@100 ppm and each treatment replicated thrice. Foliar spraying of growth regulators was done during mid-November (at flower bud differentiation stage) and mid-January (pre-fruiting stage).Observations were recorded on different vegetative characters likeplant height (cm), plant spread (cm), petiole length (cm), leaves per plant, runners per plant, different reproductive characters like days taken to first flower, days taken to fruit bud development, number of flowers per plant, number of fruits per plant and different fruit characters like Length: diameter ratio, Specific gravity, Juice (%), Total soluble solid (°Brix), Ascorbic acid (mg/100g), acidity. Plant height was measured from base of crown to tip with the help of a scale. Plant spread for North–South, and East–West direction was measured and averaged. Petiole length was measured from the base of the conjunction of the lamina with the help of a scale in first 2 basal leaves. Records were made on initiation and termination of flowering and fruiting. TSS was recorded with the help of refractometer. Juice contents were measured after crushing 20 randomly selected fruit from each harvest. Acidity was measured following standard procedures (AOAC, 1990).

Results and discussion:

Influence of plant growth regulators on vegetative growth of strawberry plant

It is clear from the data depicted in the table-1 that, there was significant effect of growth regulators on growth and runner production of plant.

Plant height (cm):

Maximum plant height was obtained from treatment T_4 GA_3@100ppm (25.7 cm) which was significantly differ from all other treatments where as minimum plant height was obtained from control. In case of plant height, NAA and BAP do not show the significant response. This might be due to the fact that exogenous application of gibberellin activated the sub apical meristem which leads shoot elongation. The rosette habit and dwarf shoots are formed on account of inactivation of sub apical meristem. This result was congruent with Guttridge, 1970; Guttridge and Thompson, 1964; Martinez *et al.*, 1994. Strawberry plants usually do not have distinct above ground stem, and hence vegetative growth following GA application was essentially reflected as increase in crown height (Sharma *et al*; 2009)

Plant spread (cm):

Plant spread was maximum in the treatment T_4 GA_3@100ppm (35.5 cm) which was significantly differ from all other treatments. whereas minimum plant spread was obtained from control (T1) 25.0cm. This might be due to spraying of Gibberellins which induced the growth by cell division, cell enlargement or both. These finding are also in conformity with Martinez *et al.*, 1994; Singh and Kaul, 1970.

Comment [MV5]: Mor[phological characters of strawberry plant

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Comment [MV7]: Cite literature to support ur findings

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Petiole length (cm):
Maximum petiole length was obtained from T_4,GA_3@100ppm (13.6 cm) which was significantly differ from all other treatments whereas, minimum petiole length was obtained from control (T1) 6.1cm. Gibberellins induced increase in length of petiole might be due to changes in cellular microtubule. Similar result was obtained by Singh and Kabul, 1970.

Numbers of leaves:
Maximum numbers of leaves (20.7) was found from treatment T_4,GA_3@100ppm. This might be due to fact that the synthesis of amino acids in plants is accelerated by application of GA3 which was indirectly exhibited by enhanced growth of strawberry plants and their parts. Whereas minimum numbers of leaves (13.2) was obtained from control (T1). This result is similar with Guttridge and Thompson, 1964.

Comment [MV8]: Cite literature to support ur findings

Runners per plant:
Strawberry is commercially propagated by runners and runner production management is an important cultivation practices in strawberry production technology. Maximum numbers of runners (7.5) were produced from the plant treated with GA_3@100 ppm (T_4). This might be due to GA_3 stimulated activity that redistributed the gibberellins in greater concentration in the crown region which later induced the runner emergence. But the minimum numbers of runner were produced in control which was at par with treatment T_5 andT_6. These results are in conformity with Martinez *et al.*, 1994. Application of GA_3 to one-year-old strawberry plants promotes vegetative growth and runner production. This may be due to inhibition of flowering and corresponding increase in epidermal and parenchymatous cell growth (Denis and Bennett, 1969). These results of the experiment were also in close agreement with Kumar Rajesh *et al*, 2012, Singh and Randhawa 1959, Singh and Koul , 1967. The increment in plant growth due to GA_3 application may be due to fact that GA_3 enhances the endogenous level of auxins in plant (Nitsch and Nitsch, 1961).

Comment [MV9]: Cite literature to support ur findings; use more recent journal articles

Influence of plant growth regulators on flowering and fruiting
Data on days taken to produce first flower, fruit bud development, no of flower/plant and no of fruits/plant depicted in Table 2 showed that there was significant impact of growth regulators on strawberry.

Days taken to produce first flower:
Minimum days taken to produce first flower (50.5) from planting were obtained from the treatment T_7 NAA @100ppm but strawberry plant took 17.6 days more to produce flower when sprayed with T_4 GA_3@100 ppm that was 68.1 days from planting which was maximum. This is because generally auxin and particularly NAA induce flowering by stimulating florigen which moved from petiole to growing tip and convert vegetative bud to flowering bud. The results are congruent with Thakur *et al*, 1991.

Comment [MV10]: Cite literature to support ur findings

Fruit bud development:
Minimum days taken for fruit bud development (54.2 days) from planting was obtained from the treatment T_7NAA @100ppm but strawberry plant took 21.4 days more to produce fruit bud when sprayed with GA_3@100 ppm and it was recorded to be 75.6 days which was maximum. *Fruit set* refers to the changes in the ovary leading to the development of the fruit. These changes are usually induced after pollination and fertilization which is triggered by NAA. The results are congruent with Thakur *et al*, 1991 and Diwedi *et al*, 2002 and Kumar *et al*, 2012.

Number of Flowers:

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Strawberry plants sprayed with NAA@100ppm possessed maximum number of flowers (24.2).Whereas, minimum number of flowers (15.6) was obtained from the control. Numbers of flowers are more in NAA treated plant due to more numbers of flowering stock arises from those plants as the stimulus (florigen) convert vegetative bud to fruiting bud by the help of exogenously applied NAA. The results are similar with Thakur *et al*, 1991.

Number of fruits:

In the treatment having NAA @ 100ppm, 93% flower converted to marketable fruits. Out of 24.2 numbers of flowers, 22.2 numbers of fruits were obtained from the above said treatment which was found to be maximum. In strawberry due to indeterminate growth habit of inflorescence, size and number of fruit reduces in the later condition. But spraying NAA can reduces this incidence and provide economic yield to the farmer (Kumar *et al.,* 2011). Minimum numbers of fruits (13.5) was found in control. Fruit set from flowering depend upon the external and internal plant factors. Maintain proper C:N ratio of the plant, providing exact quantity of nutrient and hormonal balance leads to more fruit set and all these phenomenon are directly and somewhere indirectly auxin related.

Influence of plant growth regulators on fruit quality

As far the quality of the fruit is concerned the data represented in table 3 showed that growth regulators application influenced on the physical and chemical characteristics of strawberry fruits.

Fruit length-diameter ratio:

The maximum fruit length diameter ratio 2.06 which was significantly differ from all other treatments that obtained from treatment T6, NAA@75ppm which was at par with treatment T_7(1.71). Minimum of this trait was obtained in the control. Recently, molecular analyses have confirmed the prominent role played by auxin signaling in triggering and coordinating the transition from flower to fruit. The growth of the ovary is blocked before pollination and that auxin is involved in depression of ovary growth after fertilization (Pandolfini *et al* ; 2007). So fruit size increases with exogenous application of NAA with a particular concentration. This result is similar with Kumar *et al* 2011, Khunte *et al*, 2014.

Specific gravity:

The maximum specific gravity 2.01, which was significantly differ from all other treatments which obtained from T_6,@75ppm whereas minimum specific gravity was obtained from BAP @ 100ppm. Increasing in sink strength and total solid results in increasing the specific gravity. This result is similar with Kumar *et al* 2011, Khunte *et al*, 2014.

Juice Percentage:

Highest juice percentage 94.4% was found in from the fruit taken from the plants which were sprayed with NAA @ 75 ppm (T_6) which was at par with treatment T_7(93.3%). Whereas, minimum juice percentage was found in treatment T_1 (control) .This result is similar with Kumar *et al* 2011, Khunte *et al*, 2014. This might be due to the increased vascularization in the pedicel and/or due to the increased sink strength and/or reduced senescence and respiration from the fruit.

Total Soluble Solid:

Maximum TSS 12.6 °Brix was possessed by the fruit harvested from the plant treated with NAA @75ppm (T_6), whereas minimum TSS was found from the fruits of T_1 (control). This result is similar with Kumar *et al* 2011; Kumar *et al.*, 2012 and Khunte *et al*, 2014. This might be due to

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the treatment effect on physiological accumulation of sugar and change in metabolism which eventually resulted in more retention of TSS and total sugars. By the activity of invertase enzyme, which break down sucrose into fructose and glucose, hence resulting in increased reducing sugars

Ascorbic Acid:

The data are presented in table 3 revealed that the treatments had significant effect on ascorbic acid of fruits. The maximum ascorbic acid (63.42mg/ 100g) was observed in treatment T_3 (75 ppm GA_3) while the minimum ascorbic acid of fruit (50.81 mg/100g) was observed under treatment T_5 (NAA@50ppm). Similar findings were also reported by Singh and Phogat (1983); Kumar *et al.* (2011) and Khunte *et al*, 2014. Higher ascorbic acid contents due to gibberellic acid application in 'Blood red' sweet orange as compared to control also reported by Saleem et al., 2008. This is due to positive influence on sink strength (reproductive growth) as evidenced by more TSS and juice mass (%) in fruit of auxin treated trees in comparison with control and other growth regulators like GA_3 .

Acidity:

The maximum acidity of fruit juice (0.74 %) was observed in treatment T_3 (75 ppm GA_3) while the minimum acidity of fruit juice (0.59 %) was observed with treatment T_5 (50 ppm NAA). Similar findings were also reported by Singh and Singh (1979); Kumar *et al.* (2012) and Khunte *et al*, 2014. Increasing in Titrable acidity by GA_3 was due to the consumption of sugar in form of energy to enhance the vegetative growth.

Comment [MV11]: Discuss further the results

Conclusion:

From the aforesaid discussion it is revealed that strawberry respond significantly well to the growth regulators with respect to its yield and yield attributing characters. So, for the tropical hot and humid climatic conditions, farmers are advised to for two spraying of NAA @ 100ppm and GA_3@100 ppm as foliar spray once in mid November and second in mid February in normal production practices for good vegetative growth and to get higher yield with commercial quality fruit.

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TABLE 1: Influence of plant growth regulators on vegetative growth and runner production of strawberry (*Fragaria ×ananassa*)

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Treatments	Plant height (cm)	Plant spread (cm)	Petiole length (cm)	Leaves/plant	Runners/ plant
T_1	12.4	25.0	6.1	13.2	4.0
T_2	18.3	31.3	10.1	15.4	4.5
T_3	20.9	33.2	12.7	17.5	6.4
T_4	25.7	35.5	13.6	20.7	7.5
T_5	13.7	26.6	7.4	14.5	3.7
T_6	14.1	26.8	7.7	15.6	3.6
T_7	16.3	28.2	8.8	15.4	4.7
T_8	12.6	25.4	7.5	13.3	3.6
T_9	12.7	26.0	7.6	14.2	3.5
T_{10}	13.3	26.2	7.3	14.7	4.0
SE (m)±	0.28	0.32	0.24	0.25	0.05
CD (1%)	1.14	1.43	1.05	1.13	0.30

TABLE 2: Influence of plant growth regulators on flowering & fruiting on strawberry (*Fragaria ×ananassa*)

Treatments	Days taken to first flower	Days taken to fruit bud development	Number of flower/ plant	Number of fruit/ plant
T_1	64.2	72.1	15.6	13.5
T_2	62.5	68.8	15.8	14.3
T_3	65.2	74.4	16.4	14.7
T_4	68.1	75.6	19.8	15.3
T_5	55.2	59.0	21.2	17.3
T_6	52.4	55.5	22.0	18.3
T_7	50.5	54.2	24.2	22.2
T_8	60.2	66.2	21.5	17.1
T_9	58.3	64.1	20.3	16.0
T_{10}	57.4	64.8	22.0	16.8
SE (m)±	0.27	0.24	0.24	0.23
CD (1%)	1.13	1.13	1.11	0.91

TABLE 3: Influence of plant growth regulators on quality of strawberry (*Fragaria ×ananassa*)

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Treatments	Length: diameter ratio	Specific gravity	Juice (%)	Total soluble solid (° Brix)	Ascorbic acid (mg/100g)	Acidity
T_1	1.10	1.11	70.4	5.9	53.41	0.62
T_2	1.22	1.08	84.2	7.4	63.04	0.73
T_3	1.24	1.11	83.4	7.9	63.42	0.74
T_4	1.25	1.13	81.2	8.3	61.11	0.69
T_5	1.32	1.15	92.6	10.1	50.81	0.59
T_6	2.06	2.01	94.4	12.6	51.81	0.60
T_7	1.71	1.52	93.3	12.1	55.11	0.63
T_8	1.41	1.15	92.5	9.5	58.31	0.67
T_9	1.36	1.11	91.7	9.2	55.61	0.64
T_{10}	1.12	1.01	91.5	10.1	57.21	0.66
SE (m)±	0.10	0.04	0.41	0.35	1.07	0.04
CD (1%)	0.41	0.21	1.62	1.31	2.12	0.28

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