Effect of plant growth regulators on the morpho-physiological and physico-chemical characters of Strawberry (*Fragaria* × *ananassa* Dutch.)

Abstract

In the coastal region of Odisha, an experiment was carried out to investigate the effects of several plant growth regulators, such as auxin, cytokinin, and gibberellins, on the growth, yield, and quality characteristics of strawberries. Different concentration of napthyl acetic acid(NAA), gibberellic acid(GA3) and benzyl amino purine(BAP) we are taken for the experiment to evaluate the changes in morpho-physiological and physico-chemical characteristics of strawberry.The investigation's findings showed that strawberry plants respond favorably to the administration of plant growth regulators. When it came to the generation of runners and vegetative growth, treatment GA3 at 100 ppm produced the best results.The application of NAA@ 100 ppm was found to increase various yield-attributing characteristics, such as the number of flowers or fruits per plant, the number of days taken for fruit development, and the number of days taken for the first fruiting. On the other hand, the treatment of 75 ppm NAA produced better physico-chemical characteristics, such as total soluble solid, specific gravity, juice percentage, and length to diameter ratio of the fruits. However, GA3 75 ppm had a greater ascorbic acid concentration and acidity %.

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

Introduction:

"*Fragaria"* is a prominent fruit crop species because of its fruit quality and post-harvest application. It is a genus of perennial, creeping herbs that grows naturally in various climatic zones of the world (Gaston et al., 2020). It is a member of the Rosaceae family of plants. According to Darrow (1996), Galletta and Bringhurst (1990), and Larson (1994), the cultivated strawberry (*Fragaria* × *ananassa* Duch.) is a monoecious octaploid hybrid of two mostly dioecious octaploid species, Fragaria chiloensis Duch. and Fragaria virginiana Duch. In Fragaria, the container expands into the red fruit known as a strawberry, and black specks, each representing a single genuine fruit, are found all over its surface.

The term "achenes" refers to the solitary fruit. Anthocyanins and ellagic acid are two phenolic flavonoid phytochemicals found in notably high concentrations in strawberries. According to scientific research, eating these berries may protect against neurological disorders, cancer, aging, and inflammation.

It is one of the few crops that yields rapid and extremely large returns on capital investment per unit area. Strawberry vegetative growth and reproductive activity have been reported to be enhanced by GA3 and cytokinin; strawberry output and quality have been found to be enhanced by Cycocel and NAA (Thakur et al., 1991). Strawberry is a temperate fruit with a high market price and very little output in tropical and subtropical regions. The impoverished cannot afford it because of these obstacles, and farmers hardly ever cultivate it. In light of this, the current research on strawberries was conducted to determine the ideal growth hormone and its concentration for the industrial production of high-quality strawberries in tropical climates.

Materials and Method:

Experimental site.

At the Faculty of Agriculture, Sri Sri University, Cuttack, Odisha, an experiment was carried out in 2019–20 to determine the impact of plant growth regulators on the quality, yield, and growth of strawberry (Fragaria ×ananassa) Duch. plants. This area, which is in the east and south-east coastal zone, has a tropical climate with moderate winters (December to February) and humid summers (May to June). The region receives roughly 1542 mm of rainfall annually, most of it falls in the months of July and August. In the evening, strawberry runners with about identical size and vigor were transplanted into medium-sized pots with sand as the growing medium. manure from the farmyard (1:1:1). The soil had a sandy-loam with a pH of 7.5, low levels of organic carbon (0.42%), medium levels of phosphorus that was accessible, and high levels of potash. In the trial pot, every cultural custom was adhered to exactly.

Treatment details-:

The ten treatments in the experiment were as follows: T1 was the control (water), T2 was GA3@ 50 ppm, T3 was GA3 @ 75 ppm, T4 was GA3@ 100 ppm, T5 was NAA @ 50 ppm, T6 was NAA@ 75 ppm, T7 was NAA@ 100 ppm, T8 was BAP @ 50 ppm, T9 was BAP @ 75 ppm, and T10 was BAP@100 ppm. Each treatment was replicated three times. Growth regulators were sprayed foliarly in mid-November, when flower buds were beginning to differentiate, and in mid-January, when fruit was about to ripen.

Observations recorded-:

Many vegetative characteristics, such as plant height (cm), plant spread (cm), petiole length (cm), number of leaves per plant, number of runners per plant, and days taken for the development of the first flower or fruit bud, number of flowers per plant, number of fruits per plant, and various fruit characteristics, such as length: diameter ratio, specific gravity, juice (%), total soluble solid (°Brix), ascorbic acid (mg/100g), and acidity, were noted. Using a scale, the height of the plant was measured from the base of the crown to the tip. We measured and averaged the plant spread in both the North-South and East-West directions. With the use of a scale on the first two basal leaves, the petiole length was measured from the base of the lamina's conjunction. On the start and finish of flowering and fruiting, records were kept. A refractometer was used to record the TSS. Following the crushing of twenty randomly chosen fruits from each crop, the juice content was measured. According to accepted practices, acidity was measured (AOAC, 1990).

Results and discussion:

Morpho-physiological characteristics of Strawberry

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

Treatment T4 GA3@100ppm produced the highest plant height (25.7 cm), which differed considerably from all other treatments. The control produced the lowest plant height. NAA and BAP do not exhibit a substantial reaction when it comes to plant height. This may be because gibberellin was applied exogenously, activating the subapical meristem and causing shoot elongation. The subapical meristem's inactivation causes the rosette habit and dwarf shoots to develop. According to Guttridge, 1970; Guttridge and Thompson, 1964; Martinez et al., 1994, this conclusion was consistent. Since strawberry plants often lack a distinct above-ground stem, the application of GA to promote vegetative growth resulted in an increase in crown height (Sharma et al., 2009).

By hydrolyzing protein and releasing tryptophan, GA promotes apical dominance and increases the plant height. (Katel et al. 2022).

Plant spread (cm):

The treatment T4 GA3@100ppm (35.5 cm) had the greatest plant spread, differing significantly from the other treatments. Conversely, control (T1) achieved the minimal plant spread of 25.0 cm. This could be the result of Gibberellins being sprayed, which caused growth by either cell enlargement or division, or both. These results also agree with Singh and Kaul (1970) and Martinez et al. (1994).

Petiole length (cm):

While the minimal petiole length of 6.1 cm was obtained from the control treatment (T1), the maximum petiole length of 13.6 cm was obtained from T4, GA3@100ppm, which differed considerably from all other treatments. The lengthening of the petiole that gibberellins elicit may be the result of alterations in cellular microtubules. Singh and Kabul (1970) found a similar outcome.

Numbers of leaves:

The highest number of leaves (20.7) from treatment T4, GA3@100ppm, was discovered. This could be because applying GA3 speeds up the synthesis of amino acids in plants, as seen by the increased development of strawberry plants and their components. whereas the control group (T1) had the bare minimum of leaves (13.2). This outcome is comparable to that of Guttridge and Thompson (1964).

Application of gibberellic acid in the yearly stage induces cell division in cambium cells, resulting in the production of xylem tissue in the lower internodes which provides more number of leaf formations and add mechanical support to the plant. (Katel et al. 2022).

Runners per plant:

Runners are the commercial propagators of strawberries, and one of the key cultivation techniques in strawberry production technology is runner production management. The plant treated with GA3@100 ppm produced the maximum number of runners (7.5) (T4). This could be because the activity that GA3 promoted caused the gibberellins to be reallocated and concentrated more in the crown region, which in turn caused the runner to emerge. However, the control group produced the same minimal number of runners as treatments T5 and T6. These findings are consistent with the work of Martinez et al. (1994). When strawberry plants are one year old, GA3 is applied to encourage vegetative growth and runner production. According to Dennis and Bennett (1969), this might be the result of blooming inhibition and a rise in epidermal and parenchymatous cell development. The experiment's outcomes also closely matched those of Singh and Randhawa (1959), Kumar Rajesh et al. (2012), and Singh and Koul (1967). One possible explanation for the increase in plant growth following GA3 application could be that GA3 raises the plant's endogenous auxin content (Nitsch and Nitsch, 1961).

GA3 boosts diphenols while inhibiting IAA oxidized activity resulting in a high auxin level and promoting more number of runners. (Katel et al. 2022).

Influence of plant growth regulators on flowering and fruiting

The data shown in Table 2 on the number of flowers/plant, fruit bud development, days taken to generate first flower, and number of fruits/plant indicated a substantial effect of growth regulators on strawberry.

Days taken to produce first flower:

Strawberry plants sprayed with T4 GA3@100 ppm took 17.6 days longer to generate flowers than other treatments, taking a maximum of 68.1 days from planting to produce the first blossom (50.5 days) after planting. This is due to the fact that auxin, and in particular NAA, generally stimulates florigen to travel from the petiole to the growing tip and transform the vegetative bud into a blooming bud. The outcomes align with the findings of Thakur et al. (1991).

NAA promotes cell elongation, division auxin mediated flowering pathways by triggering the endogenous hormonal cues (Dong et al. 2021)

Fruit bud development:

The treatment T7 NAA @100 ppm produced the minimum number of days required for fruit bud growth (54.2 days) after planting; however, the strawberry plant required an additional 21.4 days to create a fruit bud when sprayed with GA3 @100 ppm, with a maximum of 75.6 days reported. The term "fruit set" describes the ovarian alterations that result in the development of the fruit. Usually, these modifications occur following fertilization and pollination, which are started by NAA. The outcomes align with the findings of Thakur et al. (1991), Diwedi et al. (2002), and Kumar et al. (2012).

Number of Flowers:

Plants that were sprayed with NAA@100ppm produced the greatest amount of blooms (24.2). On the other hand, the control group produced the requisite minimum of blooms (15.6). Since more flowering stock develops from NAA-treated plants as a result of the stimulus (florigen) converting vegetative bud to fruiting bud with the aid of exogenously given NAA, there are more flowers on NAA-treated plants. The outcomes with Thakur et al., 1991 are comparable.

Number of fruits:

93% of the flowers in the treatment with 100 ppm NAA turned into commercially viable fruits. The aforementioned treatment produced 22.2 fruits out of 24.2 blooms, which was determined to be the maximum amount. In strawberries, the size and quantity of fruit decreases with time due to the inflorescence's unpredictable development pattern. However, applying NAA spray might lessen this occurrence and give the farmer a profit (Kumar et al., 2011). There were the bare minimum of fruits (13.5) in the control group. Plant characteristics both internal and extrinsic to the blooming process determine fruit set. Maintaining the plant's correct C:N ratio, giving it the right amount of nutrients, and balancing its hormones all contribute to increased fruit set, which is partially or entirely dependent on auxin.

Influence of plant growth regulators on fruit quality

The findings in Table 3 on fruit quality indicated that the application of growth regulators had an impact on the physical and chemical properties of strawberry fruits.

Fruit length-diameter ratio:

The greatest fruit length diameter ratio of 2.06 was obtained from treatment T6, and it differed considerably from all other treatments. NAA@75ppm was obtained from treatment T6, and it was comparable to treatment T7 (1.71). In the control group, the minimum of this feature was found. The important function that auxin signaling plays in initiating and coordinating the transition from flower to fruit has recently been validated by molecular investigations. Auxin is implicated in the depression of ovarian growth following fertilization, and the growth of the ovary is inhibited prior to pollination (Pandolfini et al., 2007). Thus, exogenous administration of NAA at a specific concentration results in an increase in fruit size. Similar outcomes were seen with Kumar et al. (2011) and Khunte et al. (2014).

Specific gravity:
The lowest specific gravity was obtained from BAP @ 100 ppm, while the maximum specific gravity of 2.01 was obtained from T6, @ 75 ppm, which was considerably different from all other treatments. Specific gravity rises with increases in sink strength and total solid. Similar outcomes were seen with Kumar et al. (2011) and Khunte et al. (2014).

Juice Percentage:
The fruit harvested from plants sprayed with NAA at a concentration of 75 parts per million (T6) had the highest juice percentage (94.4%), comparable to treatment T7's (93.3%). Conversely, the treatment T1 (control) group showed the lowest percentage of juice.Similar outcomes were seen with Kumar et al. (2011) and Khunte et al. (2014). This could be brought on by the pedicel's increased vascularization, the sink's increased strength, the fruit's decreased senescence, or both.

Total Soluble Solid:
Maximum TSS of 12.6 °The fruit collected from the plant treated with NAA @75ppm (T6) had the highest brix, while the fruits of T1 (control) had the lowest TSS. The findings are comparable to those of Kumar et al. (2011), Kumar et al. (2012), and Khunte et al. (2014). This could be because of how the medication affected the body's natural sugar accumulation and altered metabolism, which in turn led to a greater retention of total sugar and TSS. due to the invertase enzyme's activity, which converts sucrose into fructose and glucose and increases the amount of reducing sugars.

Ascorbic Acid:
Fruit ascorbic acid was significantly impacted by the treatments, according to the findings in Table 3. Treatment T3 (75 ppm GA3) showed the highest ascorbic acid content (63.42 mg/100g), whereas treatment T5 (NAA@50 ppm) showed the lowest ascorbic acid content (50.81 mg/100g). Similar results were also reported by Kumar et al. (2011), Khunte et al. (2014), Singh and Phogat (1983), and others. Saleem et al. (2008) also reported higher ascorbic acid concentrations in "Blood red" sweet oranges as a result of gibberellic acid application, as compared to the control.This is because auxin treatment has a beneficial effect on sink strength, or reproductive growth, as seen by the fruit of auxin-treated plants having higher TSS and juice mass (%) than control and other growth regulators like GA3.

Acidity:
Fruit juice with the highest acidity (0.74%) was found in treatment T3 (75 ppm GA3), while treatment T5 (50 ppm NAA) had the lowest acidity (0.59%). Similar results were also reported by Kumar et al. (2012), Khunte et al. (2014), and Singh and Singh (1979). Because GA3 was consuming sugar as energy to promote vegetative growth, there was an increase in titrable acidity.

GA3 decreases titrable acidity of strawberry by increasing the concentration of total soluble solid. (Kumar et al. 2017)

Conclusion:

From the explanation above, it is clear that strawberries respond very well to growth regulators in terms of yield and characteristics that contribute to yield. Therefore, farmers are advised to apply two foliar sprays of NAA @ 100 ppm and GA3 @ 100 ppm in mid-November and mid-February, respectively, in accordance with standard production practices to promote good vegetative growth and a higher yield of commercially grade fruit in the tropical hot and humid climate.

References:

AOAC (1990). Official method analysis, Association of Analytical Chemist, Washington D.C. , U.S.A.

Darrow GM. 1996. The Strawberry: History,breeding and physiology, Chapter 20, Holt, Rinehart and Winston, New York.

Dennis, F.G. and Bennitt, H.O. (1969). Effect of Gibberellic acid and deblossming on flowering, runner and inflorescence development of strawberry ,J.Amer. Soc., 94: 558-560.

Diwivedi, M.P. Negi, K.S., Jindal, K.K., Rana H.S. (2002), Influence of photoperiod and bioregulators on vegetataive growth of Strawberry, Adv. Hort & Forestry, 7: 29-3

Dong X., Li Y., Guan Y, Wang S., Luo h., Li X., Li H., Zhang Z. 2021 Auxin induced auxin response factor 4 activates APETALA 1 & FRUITFUL to promote flowering in woodland strawberry, Horticulture research 8;115.

Galleta GJ and Bringhrust RS. 1990. Strawberry management. (In): Small Fruit Management , chapter 3, Galleta G.J. And Mimelrick (Eds), prentice hall. Englewood cliffs, New Jersey.

Guttridge, C.G., 1970. Interaction of photoperiod, chilling and exogenous gibberellic acid on growth of strawberry petioles. Ann. Bot. 34, 349–364.

Guttridge, C.G., Thompson, P.A., 1964. The effect of various gibberellins on growth and flowering in perpetual fruiting and seasonal fruiting strawberries and in Duchesnea indica. J. Exp. Bot. 15, 631–646.

Gaston A., Osorio S., Donoyes B., Rothan C. 2020. Applying solanaceae strategies to strawberry crop improvement. Trends in plant science ,25(2),130-140.

Khunte S.D. Kumar A, Kumar V, Singh S, Saravanan S.2014. Effect of Plant Growth Regulators and Organic Manure on Physicochemical Properties of Strawberry (*Fragaria x ananassa*Duch.) *cv.* Chandler, International Journal Of Scientific Research And Education**,** 7(2) 1424-1435

Kumar R, Bakshi M, Singh B.D., 2012, Influence of plant growth regulators on growth, yield and quality of strawberry (Fragaria × ananassa Duch.) under U.P. Subtropics, The Asian journal of Horticulture, 7(2), pp: 434-436

Kumar, R., Saravanan, S., Bakshi, Parshant and Srivastava, J.N. (2011).Influence of plant growth regulators on growth, yield and quality of strawberry (*Fragaria* x *ananassa*Duch.) *cv.* Sweet Charlie. *Progressive horticulture. 43 (2):264- 267.*

Katel S., Mandal H.R., Katel S.,Yadav S.P.S, Lamshal Bs.2022 Impact of plant growth regulators in strawberry plants; a review, Heliyon, 8(12); e11959.

Kumar R., Singh Sp., Tiwari A., M.S, Patidar VL. 2017 Effect of gibberellic acid on fruit yield and quality of cape gooseberry. Internation journal of advanced biological research. 7(4); 724-727.

Larson KD. 1994. Strawberry (In): Handbook Of Environmental Physiology Of Fruit Crops . Temperate Crops, Volume 1, Pp:271-297 ,Schaffer, B. and Anderson, P.C.(Eds) .CRC, Press, Inc,

Martinez, G.A., Chaves, A.R., Anon, M.C., 1994. Effect of gibberellic acid on ripening of strawberry fruit (Fragaria ananassa Duch.). J. Plant Growth Reg. 13 (2), 87–91. Pandolfini T., Molesini B., Spena A. Molecular dissection of the role of auxin in fruit initiation. Trends Plant Sci. 2007;12:327–329

Nitsch J.P. and Nitsch . C. (1961). Growth factors in totamto fruit plant growth regulators, Klein R.M. (Ed) Lowa State University press, America. Pp: 687-705

Pandolfini T, Rotino GL, Camerini S, Defez R, Spena A. (2002) Optimisation of parthenocarpic fruits in industrial tomatoes. BMC Biotechnol2: 1–11

Sharma R.R, Singh R, 2009; Gibberellic acid influences the production of malformed and button berries, and fruit yield and quality in strawberry (Fragaria _ ananassa Duch.), Scientia Horticulturae 119 , 430–433.

Singh , J.P. and Randhaw,G.S. (1959). Effect of Gibberellic acid and paracholorophenoxy acetic acid on growth and fruitfulness in Strawberry. Indian J. Hort., 16:14-17.

Singh, R., Kaul, G.L., 1970. Effect of gibberellic acid on strawberry. I. Growth and fruiting. Proc. Int. Symp. Hortic., 315–327.

Singh, H. and Singh, R. (1979). Effect of GA3 and manuring on fruit quality of strawberry .Punjab Hort. J., 34:207-211.

Singh, O. P. and Phogat, K. P. S. (1983). Effect of plant growth regulators on strawberry. Prog. Hort . J., 15: 64-68.

Thakur, A.S., Jinda, K.K. and Sud, A. (1991). Effect of plant growth regulators on Strawberry. Indian J. Hort., 48: 286-290.

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

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*)

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