

Original Research Article

Influence of plant growth regulators on quality attributes of pineapple (*Ananas comosus* L.)

ABSTRACT

Aims: A trial was conducted to investigate the influence of plant growth regulators (PGRs) on the growth and quality attributes of pineapple fruits.

Study design: The experiment was arranged in a randomized completed block design (RBCD) with three replications using 25 plants per replication.

Place and Duration of Study: The experiment was carried out between 2020 and 2021 at the Central Horticultural Experiment Station, Aignia, Bhubaneswar, India.

Methodology: The application of ~~plant growth regulators~~PGRs was done at the flower initiation stage where spraying was done directly onto each fruit, including the crown. The control was a sample without any application of PGRs. Fruits were harvested at the ripe stage and an analysis of different growth and quality parameters were done.

Results: Application of ~~plant growth regulators~~PGRs significantly improved yield and quality attributes of pineapple. Application of NAA 200 mgL⁻¹ (T3) was found to be the most effective in enhancing absolute growth rate (2.65 g day⁻¹), fruit weight (1.58 kg), and fruit/crown ratio (6.38). It was also evident that application of NAA 200 mgL⁻¹ improved fruit quality in terms of soluble solid contents (17.67 °Brix), soluble solid contents to acid ratio (19.49), reducing sugar (3.54%), and total sugar content (12.38%). Higher pulp content (73.89%), pulp-to-peel ratio (3.49) and juice content (54.50%) were also observed with NAA 200 mgL⁻¹.

Conclusion: NAA 200 mgL⁻¹ significantly improved fruit growth i.e. fruit weight, fruit-to-crown ratio, and absolute growth rate. It also enhanced the quality attributes of pineapple fruits i.e. pulp content, pulp-to-peel ratio, juice content, pH, soluble solid contents, SSC to acid ratio, reducing sugar, and total sugar content.

Keywords: Pineapple, NAA (naphthalene acetic acid), GA (gibberellic acid), BR (brassinosteroid), MD2, growth, quality, plant growth regulators (PGRs).

1. INTRODUCTION

Pineapple (*Ananas comosus*) is a popular tropical fruit known for its unique taste and aroma. The fruit is known for its unique flavor due to the presence of several volatile compounds in small amounts and complex mixtures. Additionally, pineapples are a rich source of minerals and vitamins that have several health benefits. It belongs to the family Bromeliaceae and originated in South America [31, 26]. Pineapple is presently considered the third most important fruit crop in world production after banana and citrus [19]. Fresh pineapple fruit contains substantial amounts of vitamin A, vitamin B complex (thiamine, riboflavin, niacin, pyridoxine, folic acid), and vitamin C. Moreover, pineapple fruit is rich in minerals i.e. potassium, calcium, magnesium, and phosphorus [4]. It contains a proteolytic enzyme called bromelain, which helps in the digestion process by breaking down proteins [2]. Uniform fruit size is a major limitation that affects pineapple farmers in the MD-2 variety. Therefore, to address this issue various plant growth regulators (PGRs) with different concentrations were applied. Various metabolic processes, such as cell division, differentiation and expansion, organogenesis, and germination, are controlled by ~~plant regulators~~PGRs, which are used to

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enhance fruit quality. The quality of the fruit also plays an important role in determining the shelf life as well as the choice of purchasing for customers. It determines the acceptance by the consumer and they are willing to pay a higher price for good quality fruits. In this context, the primary purpose of this research work was to investigate the influence of [plant growth regulator](#) PGRs in enhancing the fruit growth and quality attributes of pineapple.

2. MATERIAL AND METHODS

The experiment was carried out between 2020 and 2021 at the Central Horticultural Experiment Station, Aignia, Bhubaneswar, India. The experimental site is located in the eastern coastal region of India (20° 27' N latitude and 85° 40' E longitude). Pineapple variety MD-2 was [taken-used](#) for the study. Different concentrations of PGRs [was-were](#) sprayed on pineapple fruit at different stages by using a hand sprayer until the fruits were wet to runoff. Additional fruits were also sprayed with distilled water as the control.

2.1 Experimental details

The experiment consisted of 7 treatments, comprising NAA (100 and 200 mg L⁻¹), GA (50 and 100 mg L⁻¹), and Brassinosteroid (2 and 4 mg L⁻¹). Spraying of the treatments was done at the flower initiation stage, directly onto each fruit, including the crown. The control was a sample without any application of PGRs from the beginning of the research until the pineapple harvest. The experiment was arranged in a randomized completed block design (RBCD) with three replications using 25 plants per replication. The treatments were comprised of: T1 – control; T2 - NAA 100 mg L⁻¹; T3 - NAA 200 mg L⁻¹; T4 – GA 50 mg L⁻¹; T5 - GA 100 mg L⁻¹; T6 – BR 2 mg L⁻¹; T7 - BR 4 mg L⁻¹.

2.2 Analysis of growth parameters

Fruits were harvested at the ripe stage. Fruits were weighed using a digital weighing machine. Pineapple fruits were peeled and the core was removed using a knife then [100 grams of the](#) pulp was weighed [100 grams](#) from [where-which-the](#) juice was extracted for estimating the juice content per 100 grams of pulp. Dry weights were taken by keeping pulp in Petri plates and drying was done inside an oven drier for 72 hours at 60°C.

2.3 Analysis of quality parameters

The total soluble solids (TSS) content was recorded with the help of a digital refractometer. The pH of the juice was recorded with a pH meter. The titrable acidity, reducing sugar and total sugar was determined by following the methods of Ranganna (1986). The ascorbic acid or vitamin C of pineapple fruits was determined by following the standard technique as described by AOAC [3]. The 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay was also carried out according to Blois [8] method. Protein content was measured by the Bradford method [10] using BSA as standard.

3. RESULTS AND DISCUSSION

3.1 Growth Attributes

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The duration of fruit maturity was significantly influenced by plant growth regulators treatments. From table 1, it was observed that the lowest number of days (100.00 days) from flower initiation to fruit maturity was found in treatment T7 (BR 4 mg L⁻¹) followed by treatment T6 (BR 2 mg L⁻¹) i.e. 101.67 days and highest number of days from flower initiation to fruit maturity (107.00 days) was recorded in the treatment T1 (control). The shorter duration of flower initiation to fruit maturity is due to the early ripening induction of the pineapple fruits and it is a well-known fact that in non-climacteric fruits the respiratory burst and rise in ethylene production are not evident. Therefore, increased levels of brassinosteroids (BRs) hormone might have promoted ripening through complex interactions [12]. Brassinosteroid is involved in stimulating ethylene production, which may, in turn, promote the biosynthesis of abscisic acid, which both directly prevent tissue growth and enhance the fruit ripening process [35, 15, 5]. Brassinosteroid application has been found to induce early maturation of sweet cherry cv. 'Tulare' and 'Bing' (Mandava and Wang 2016). The same results were supported Chai *et al.* [11] in strawberries and Wang *et al.* [38] in sweet orange.

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Fruit weight varied significantly with the application of plant growth regulator PGRs (Table 1). The data indicated that the fruit weight was significantly increased when the pineapple fruits were treated with NAA and GA. Maximum fruit weight was observed in T3 i.e. NAA 200 mg L⁻¹. There was a substantial increase in fruit weight i.e. 1.58 kg when treated with NAA 200 mg L⁻¹ (T4) followed by fruits treated with NAA 100 mg L⁻¹ (T2) when compared to control i.e. T1 (1.30 kg). When compared to the control (T1), there is a 21.54% increase in fruit weight in T3 (NAA 200 mg L⁻¹). Both the concentration of Gibberellic acid (50 and 100 mg L⁻¹) also showed a significant increase in fruit weight when compared to the control shown in Table 1. Application of brassinosteroids doesn't show much variation with control and it was at par. Various treatment data showed that there is a significant variation in crown weight when fruits are treated with growth regulators PGRs. It is evident from the data that with the increase in fruit weight the crown weight decreases. Therefore, maximum crown weight was observed in control (T1 – 230.04 g) compared to other treatments which were at par with fruits treated with brassinosteroids (T6 – 226.72 g and T7 – 224.17 g). Data (Table 1) also revealed that the fruit-to-crown ratio was significantly higher under treatment T3 (NAA 200 mg L⁻¹) i.e. 6.38 followed by T2 (NAA 100 mg L⁻¹) i.e. 6.03 in comparison to T1 (control) i.e. 4.64. It is clearly observed that higher fruit weight implies a higher fruit-to-crown ratio. Data (Table 1) revealed that the absolute growth rate (g day⁻¹) ranged from 1.97 to 2.65 g per day when fruits are sprayed with different concentrations of plant growth regulator PGRs. The highest absolute growth rate based on dry weight was observed in fruits treated with NAA 200 mg L⁻¹ (T3 – 2.65 g day⁻¹), whereas, the lowest absolute growth rate was observed in fruits with no treatments i.e. control (T14 – 1.97 g day⁻¹), T5 (GA 100 mg L⁻¹), T2 (GA 50 mg L⁻¹), and T4 (NAA 200 mg L⁻¹) showed very little variation i.e. 2.51, 2.53, and 2.54 g day⁻¹ respectively, which is at par with each other. PGRs play an important role in increasing plant growth as well as quality, additionally, affecting vegetative and fruit production [37, 22, 18]. Findings indicated that fruit weight, fruit-to-crown ratio, as well as absolute growth rate of fruits, are enhanced by the application of NAA and GA. The highest fruit weight, fruit-to-crown ratio, and absolute growth rate of fruits were observed in fruits treated with NAA 200 mg L⁻¹. NAA can increase the fruit size as it is proven that there is an increase in cell division and cell elongation caused by NAA and spraying of NAA may have increased the cell wall elasticity, thereby resulting in enlargement due to increasing the rate of growth in fruits, which leads to the formation of larger fruits [16, 25]. These findings were supported by Maibangra and Ahmed [19], Suresh *et al.* [34] and Senapati *et al.* [30] in pineapple, Agrawal and Dikshit [1] in sapota, Stern *et al.* [33] in Japanese plum, and Hanafy *et al.* [14] in orange.

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Table 1: Influence of plant growth regulators PGRs on growth attributes of pineapple fruits

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Treatments	Fruit weight (kg)	Crown weight (g)	Fruit/crown ratio	Absolute growth rate (g day ⁻¹)	Days from flower initiation to maturation
T1 -Control	1.30	230.04	4.64	1.97	107.00
T2 - NAA 100 mg L ⁻¹	1.52	215.26	6.03	2.53	104.00
T3 - NAA 200 mg L ⁻¹	1.58	214.34	6.38	2.65	105.00
T4 - GA 50 mg L ⁻¹	1.48	212.03	5.99	2.54	102.00
T5 - GA 100 mg L ⁻¹	1.49	212.73	6.01	2.51	103.33
T6 - BR 2 mg L ⁻¹	1.31	226.72	4.79	2.15	101.67
T7 - BR 4 mg L ⁻¹	1.32	224.17	4.91	2.22	100.00
SEm (±)	0.015	3.043	0.044	0.029	0.991
CD (5%)	0.05	9.38	0.14	0.09	3.05

3.2 Quality Attributes

The pulp content (%) is shown in Fig.1(a). Data revealed that fruits treated with NAA 200 mg L⁻¹ (T3 – 73.89%) showed maximum pulp content percentage followed by fruits treated with NAA 100 mg L⁻¹ (T2 – 73.72%), GA 100 mg L⁻¹ (T5 – 73.59%), and GA 50 mg L⁻¹ (T4 – 73.5%). The lowest pulp content percentage was observed in the control (T1 – 71.89%) with no treatments followed by fruits BR 2 mg L⁻¹ (T6 – 72.03%) and BR 4 mg L⁻¹ (T5 – 72.33%). Application of NAA 200 mg L⁻¹ (T3), increases the pulp content by 2.8% when compared with the control (T1). The lowest percentage of peel content i.e. 21.20% was observed in T3 (NAA 200 mg L⁻¹) followed by T2 (NAA 100 mg L⁻¹), T5 (GA 100 mg L⁻¹), and T4 (GA 50 mg L⁻¹) i.e. 21.36, 21.44, and 21.50% respectively, whereas, the highest value was observed in T1 (control) with 22.45% as shown in Fig. 1(b). The maximum pulp-to-peel ratio (3.49) was observed with treatment NAA 200 mg L⁻¹ while the minimum ratio (3.15) with T6 (BR 2 mg L⁻¹) and fruits treated with T7 (BR 4 mg L⁻¹) and T1 (control) i.e. 3.20 as shown in Fig. 1(c). The percentage of juice content was also significantly influenced by the application of plant growth regulator PGRs Fig. 1(d). It is observed that the maximum percent of juice content i.e. 54.50% was observed in fruits treated with NAA 200 mg L⁻¹ (T3) followed by 54.00% in fruits treated with NAA 100 mg L⁻¹ (T2), whereas, minimum juice content was observed in T1 (control) and T6 (BR 2 mg L⁻¹) i.e. 52.50%. The pulp content, as well as pulp to peel ratio of pineapple fruits, had been observed to be the maximum when pineapple fruits are treated with NAA. This might be due to fruit development results in fruit enlargement as discussed earlier in this paper. Similar findings were reported by Pal *et al.* [23] and Senapati [31] in pineapple. According to Sandhu [28], the application of NAA raised the endogenous level of the hormone fruit, which increases fruit size and juice content percentage due to cell expansion by auxin. These findings corroborate with Sarkar *et al.* [29] in pineapple and Kumar *et al.* [17] in guava.

Pineapple fruit treated with plant growth regulator PGRs significantly increased the pH of the juice (Table 2). The pH was observed maximum in fruits treated with NAA 200 mg L⁻¹ (T3) i.e. 3.81 followed by T2 - NAA 100 mg L⁻¹ (3.78), T4 - GA 50 mg L⁻¹ (3.74), and T5 - GA 100 mg L⁻¹ (3.72). The minimum pH of juice i.e. 3.62 was observed in T1 (control) followed by T6 (BR 2 mg L⁻¹) i.e. 3.64. Similar results were observed in the soluble solid contents (SSC) of fruits when the fruits were treated with growth regulator PGRs (Table 2). Various treatment data showed that there is a significant increase in SSC when fruits are treated with growth regulators PGRs such as NAA. Maximum SSC of fruits was observed when fruits are sprayed with NAA 200 mg L⁻¹ (T3) i.e. 17.67 °B followed by NAA 100 mg L⁻¹ (T2) i.e. 17.40 °B. The lowest SSC was observed in fruits with no treatments (T1) i.e. 16.80 °B followed by

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fruits treated with BR 2 mg L⁻¹ (T6) i.e. 16.83 °B. When compared to the untreated fruits i.e. T1 there is an increase of 5.18% in SSC when treated with NAA 200 mg L⁻¹. The titrable acidity (Table 2) of the pineapple juice among different treatments increased ranging from 1.02-1.24% citric acid. Data about acidity showed that fruits treated with NAA 200 mg L⁻¹ (T3) and GA 50 mg L⁻¹ (T4) showed the lowest citric acid content i.e. 1.02% whereas the highest acidity was observed in control (T1) i.e. 1.24%. Thus, fruits sprayed with NAA 200 mg L⁻¹ (T3 – 19.49) showed maximum SSC to acid ratio followed by NAA 100 mg L⁻¹ (T2 – 18.01), whereas, the lowest was observed in fruits with no treatment control (T1 – 14.25). The reducing sugar ranged from 3.02 to 3.54%. The maximum percentage of reducing sugar was observed in fruits treated with NAA 200 mg L⁻¹ (T3 – 3.54%) followed by NAA 100 mg L⁻¹ (T2 – 3.14%), meanwhile, the minimum percentage of reducing sugar was observed in fruits with no treatment i.e. control (T1 – 3.02%). Similarly (Table 2), total sugar was found highest in NAA 200 mg L⁻¹ (T3 – 12.38%) followed by NAA 100 mg L⁻¹ (T2 – 12.18%), whereas, the lowest was observed fruits with no treatment i.e. control (T1 – 11.10%). Data (Table 2) pertaining to the percentage of non-reducing sugar was shown. Non-reducing sugar ranges from 8.36 to 9.03% when fruits are sprayed with different concentrations of PGRs. Across treatments highest non-reducing sugar percent was observed in T2 (NAA 100 mg L⁻¹) i.e. 9.03% followed by T4 (GA 50 mg L⁻¹) i.e. 8.86% and T3 (NAA 200 mg L⁻¹) i.e. 8.84%. Whereas, T1 (control or only water application) showed the lowest percentage of non-reducing sugar i.e. 8.36%. The vitamin C content ranged from 42.22 to 53.33 mg per 100 ml (Table 2). Vitamin C content showed a similar trend as the acidity of the fruit juice (Table 2). The maximum vitamin C content was estimated in fruits with no treatment T1 (53.33 mg per 100ml), meanwhile, the minimum vitamin C was observed in fruits treated with NAA 200 mg L⁻¹ (T3 – 42.22 mg per 100ml) followed by fruits treated with GA 50 mg L⁻¹ (T4 – 44.44 mg per 100ml). Protein content was significantly influenced by different treatments of plant-growth-regulators PGRs. Fruits treated with Gibberellic acid GA 50 mg L⁻¹ (T4 – 0.69%) and Gibberellic acid A 100 mg L⁻¹ (T5 – 0.68%) were higher across treatments. In contrast, the protein content of the fruits treated with no treatment (T1) i.e. 0.51% was the lowest across the treatments (Table 3). Concerning total sugar (%), reducing sugar (%), soluble solid content (SSC), acidity, and SSC/acid ratio the results indicated that spraying fruits with NAA recorded the maximum total sugar, reducing sugar, SSC, and SSC/acid ratio and minimum acidity. This might be due to the action of auxin in the quick metabolic transformation of starch and protein in the soluble compound and the rapid translocation of sugar from leaves to the developing fruit [30]. These findings were in agreement with earlier findings of Pal *et al.* [23] and Bhowmick *et al.* [7] in pineapple. And this influence the SSC/acid ratio where the increase in SSC increase the SSC/acid ratio. Citric acid, as well as ascorbic acid, was higher in fruits with no treatment i.e. control with lowest in fruits treated with NAA. The decrease in the acidity of NAA treated fruits might be due to the effectiveness of NAA in increasing sugar content as discussed earlier. And percent acidity and pH are inversely related to each other, where lower acidity results in higher pH [13]. Several studies reported that high ascorbic acid results in higher antioxidant activity. Therefore, the control i.e. with no treatments showed maximum antioxidant activity compared to other treatments [26, 6,]. The best treatment in terms of higher protein content is obtained from fruits treated with GA. According to Huizen *et al.* [39], there is a change observed in the polypeptide in pea fruit when treated with gibberellin treatment. It might be due to the regulation of gibberellin on some inhibitory genes, which may lead to the accumulation of more protein content [9].

4. CONCLUSION

The findings of the present study clearly reveal that significant variation was found in fruits treated with different concentrations of plant-growth-regulators PGRs when compared to fruits with no treatment. NAA 200 mg L⁻¹ significantly improved fruit growth i.e. fruit weight, fruit-to-

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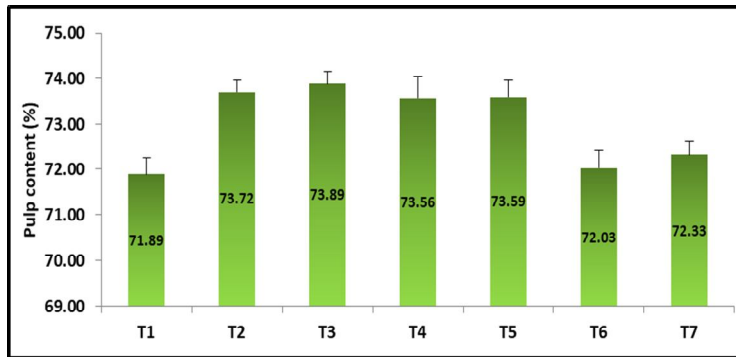
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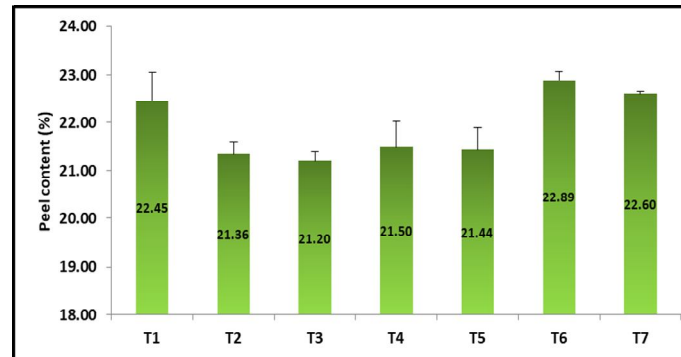
crown ratio, and absolute growth rate. It also enhanced the quality attributes of pineapple fruits i.e. pulp content, pulp-to-peel ratio, juice content, pH, soluble solid contents, SSC to acid ratio, reducing sugar, and total sugar content. Hence, the application of NAA 200 mgL⁻¹ is recommended for getting uniform fruits with better fruit weight as well as to obtain better quality fruits.

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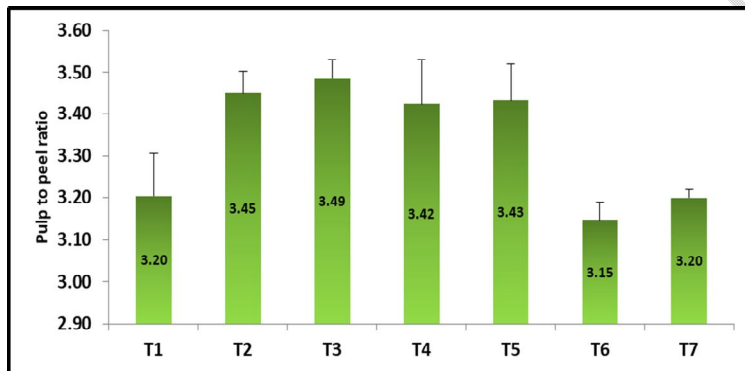
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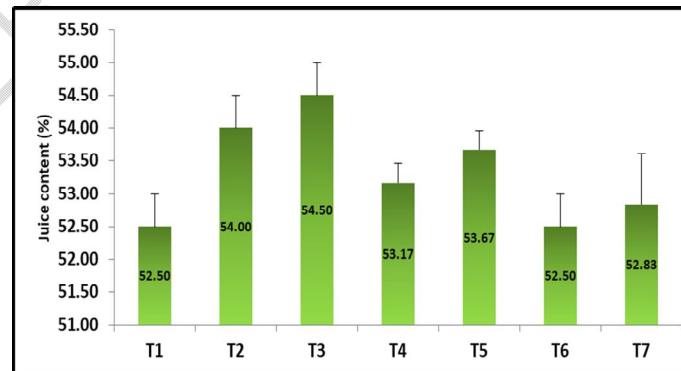
(a)



(b)



(c)



(d)

Fig. 1: Influence of [plant growth regulators PGRs](#) on (a) pulp content, (b) peel content, (c) pulp to peel ratio, and (d) juice content of pineapple fruits. Bar show standard errors (\pm).

*T1 – control; T2 - NAA 100 mg L⁻¹; T3 - NAA 200 mg L⁻¹; T4 – GA 50 mg L⁻¹; T5 - GA 100 mg L⁻¹; T6 – BR 2 mg L⁻¹; T7 - BR 4 mg L⁻¹

Comment [A12]: Need to have a statistical analysis to indicate significant differences between treatments.

Table 2: Influence of plant growth regulators PGRs on quality attributes of pineapple fruits

Treatments	pH (juice)	SSC (°B)	Acidity (%)	SSC/ Acid ratio	RS (%)	NRS (%)	TS (%)	AA (mg 100ml ⁻¹)	Antioxidant activity (%)	Protein content (%)
T1 -Control	3.62	16.80	1.24	14.25	3.02	8.36	11.38	53.33	80.14	0.51
T2 - NAA 100 mg L ⁻¹	3.78	17.40	1.07	18.01	3.14	9.03	12.18	47.77	74.29	0.61
T3 - NAA 200 mg L ⁻¹	3.81	17.67	1.02	19.49	3.54	8.84	12.38	42.22	71.05	0.63
T4 - GA 50 mg L ⁻¹	3.74	16.97	1.02	16.73	3.11	8.86	11.97	44.44	72.76	0.69
T5 - GA 100 mg L ⁻¹	3.72	16.93	1.07	15.87	3.10	8.83	11.93	47.77	74.29	0.68
T6 - BR 2 mg L ⁻¹	3.64	16.83	1.18	14.34	3.05	8.37	11.41	51.11	79.05	0.52
T7 - BR 4 mg L ⁻¹	3.67	16.87	1.13	14.97	3.08	8.45	11.53	50.00	76.19	0.53
SEm (±)	0.012	0.271	0.059	0.616	0.036	0.146	0.143	1.248	1.635	0.014
CD (5%)	0.04	0.84	0.18	1.90	0.11	0.45	0.44	3.85	5.04	0.04

*SSC : Soluble solid content, RS : Reducing Sugar, NRS : Non-Reducing Sugar, TS : Total sugar, AA : Ascorbic acid (vitamin C)

Comment [A13]: Need to have a statistical analysis to indicate significant differences between treatments.

REFERENCES

1. Agrawal S, Dikshit SN. Studies on the effect of plant growth regulators on growth and yield of sapota (*Achras sapota* L.) cv. Cricket Ball. *Indian J Agric Res.* 2008;42:207-211.
2. Amini A, Masoumi-Moghaddam S, Ehteda A, Morris DL. Bromelain and N-acetylcysteine inhibit proliferation and survival of gastrointestinal cancer cells in vitro: significance of combination therapy. *J Exp Clin Cancer Res.* 2014;33 (1): 92.
3. AOAC. Official methods of analysis of the Association of Official Analytical Chemists, 15th edn: Association of Official Agricultural Chemists, Arlington VA; 1990.
4. Assumi SR, Singh PT, Jha AK. In book: In: Tropical Fruit Crops: Theory to Practical. SN Ghosh and RR Sharma (Eds.). Edition: 1st Edition. Chapter: Pineapple (*Ananas comosus* L. Merr.). Jaya Publishing House: New Delhi; 2021.
5. Ayub RA, Bosetto L, Galvao CW, Etto RM, Inaba J, Lopes PZ. Abscisic acid involvement on expression of related gene and phytochemicals during ripening in strawberry fruit *Fragaria x ananassa* cv. *Camino Real Sci Hort.* 2016;203:178-184.
6. Beltrán-Orozco MC, Oliva-Boba TG, Gallardo-Velázquez T, Osorio-Revilla T. Ascorbic acid, phenolic content, and antioxidant capacity of red, cherry, yellow and White types of pitayas cactus fruit (*Stenocereus stellatus* Riccobono). *Agrociencia.* 2009;43:153-162.
7. Bhomick N, Ghosh SK, Munsu PS, Deb P, Ghosh A. Effect of integrated nutrient management on flowering and fruiting characteristics of pineapple.cv. Mauritius. *Journal of Crop and Weed.* 2017;13(2):144-156.
8. Blois MS. Antioxidants determination by the use of a stable free radical *Nature*; 1958;1199-1200.
9. Bora RK, Sarma CM. Effect of Gibberellic Acid and Cycocel on Growth, Yield and Protein Content of Pea. *Asian Journal of Plant Sciences.* 2006;5:324-330.
10. Bradford MM. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Anal Biochem.* 1976;72:248-254.
11. Chai Y, Zhang Q, Tian L, Li CL, Xing Y, Qin L, Shen YY. Brassinosteroid is involved in strawberry fruit ripening. *Plant Growth Regul.* 2013;69:63–69. <https://doi.org/10.1007/s10725-012-9747-6>
12. Fortes AM, Teixeira RT, Agudelo-Romero P. Complex Interplay of Hormonal Signals during Grape Berry Ripening. *Molecules.* 2015;20(5):9326-9343.
13. Gilani SA, Basit A, Sajid M, Shah ST, Ullah I, Mohamed HI. Gibberellic acid and boron enhance antioxidant activity, phenolic content, and yield quality in *Pyrus communis* L. *Gesunde Pflanzen.* 2021;73(4):395-406. <https://doi.org/10.1007/s10343-021-00555-5>
14. Hanafy-Ahmed AH, Khalil MK, Abd El-Rahman AM, Nadia AMH. Effect of Zinc, Tryptophan and Indole Acetic Acid on Growth, Yield and Chemical Composition of Valencia Orange Trees. *J Appl Sci Res.* 2012;8(2):901-914.
15. Jia HF, Chai YM, Li CL, Lu D, Luo JJ, Qin L, Shen YY. Abscisic acid plays an important role in the regulation of strawberry fruit ripening *Plant Physiol.* 2011;157(1):88-199.

16. Kaseem HA, Al-Obeed RS, Ahmed MA, Omar AKH. Productivity, fruit quality and profitability of jujube trees improvement by preharvest application of agro-chemicals. *Middle East J Sci Res.* 2011;9:628-637.
17. Kumar R, Tiwari R, Kumawat BR. Quantitative and qualitative enhancement in guava (*Psidium guajava* L.) cv. Chittidar through foliar feeding. *International Journal of Agricultural Sciences.* 2013;9(1):177-181.
18. Leclerc, Me'lanie, Caldwell CD, Lada RR, Norrie J. Effect of plant growth regulators on propagule formation in *Hemerocallis spp.* and *Hosta spp.* *Hort Sci.* 2006;41(3):651–653.
19. Maibangra S, Ahmed F. Effect of post flowering spray with NAA and GA₃ on ratoon pineapple, *Ann of Agri Res.* 2000;21(1):133-134.
20. Malézieux, E, Cote, F, Bartholomew, D.P.. Crop environment, plant growth and physiology. In: *The Pineapple, Botany, Production and Uses.* D.P. Bartholomew, R.E. Paull and K.G. Rohrbach (eds). Wallingford, UK: CAB International. 2003:69-108.
21. Mandava B, Wang Y. Effect of brassinosteroids on cherry maturation firmness and fruit quality. *Acta Hortic.* 2016;1139:451–458.
22. Ouzoundidou, G, Papadopoulou P, Giannakoula A, Ilias I. Plant growth regulators treatments modulate growth, physiology and quality characteristics of *Cucumis melo* L. plants. *Pak J Bot.* 2008;40:1185–1193.
23. Pal R, Mahato SK, Chhetri, Binoy, Suresh CP. Growth regulators influencing yield and quality of pineapple (*Ananas comosus* L. Merr). *Eco. Env and Cons.* 2015;21(2): 879-884.
24. Ranganna S. *Handbook of Analysis and Quality Control for Fruit and Vegetable Products.* Tata McGraw Hill Publishing Co. Ltd.: New Delhi; 1986:190-210.
25. Ranjan R, Purohit SS, Prasad V. *Plant Hormones: Action and Application.* Agribios, India. 2003;183-189.
26. Samee W, Engkalohakul M, Nebbua N, Direkrojanavuti P, Sornchaitawatwong C, Kamkaen N. Correlation Analysis between Total Acid, Total Phenolic and Ascorbic Acid Contents in Fruit Extracts and Their Antioxidant Activities. *Thai Pharm Health Sci J.* 2006;1:196–203.
27. Samson JA. *Tropical Fruits.* Longman Group Limited, London; 1980.
28. Sandhu, S. Improving lemon [*Citrus limon* (L.) Burm.] quality using growth regulators. *Journal of Horticultural Science.* 2013;8(1):88-90.
29. Sarkar A, Pongen A, Sema A, Kanaujia SP. Influence of foliar application of nutrients and growth regulators on yield and quality in pineapple (*Ananas comosus* L.). *Annals of Plant and Soil Research.* 2022;24(2):300-304.
30. Senapati SK, Patel MK and Sahoo SC. Effect of integrated manuring and growth regulators on yield and quality of pineapple (*Ananas comosus* L.Merr.) *The Pharma Innovation Journal.* 2020;9(5):38-40
31. Senapati SK. Effect of integrated manuring and growth regulators on pineapple (*Ananas comosus* L. Merr) grown as a component crop in coconut based cropping system model. Ph.D. Thesis, OUAT. 2020.
32. Silva D, Nogueira GDR, Duzzioni AG, Barrozo MAS. Changes of antioxidant constituents in pineapple (*Ananus comosus*) residue during drying process. *Industrial Crops and Products.* 2013;50: 557-562.

33. Stern RA, Flaishman M, Ben-Arie R. Effect of synthetic auxins on fruit size of five cultivars of Japanese plum (*Prunus saliciana* Lindl.). *Scientia Horticulturae*, 2007;112:304-309.
34. Suresh CP, Pal R, Deb P, Bhutia KD, Roy A, Hasan MA. Effect of NAA and Ethrel on yield and quality of pineapple (*Ananas comosus* L. Merr), Newsletter of the pineapple Working Group, International Society Horticultural Science. Hawaii. 2010;17:20.
35. Symons GM, Davies C, Shavrukov Y, Dry IB, Reid JB, Thomas MR. Grapes on steroids. Brassinosteroids are involved in grape berry ripening. *Plant Physiol*. 2006;140:150-158.
36. Van Huizen R, Ozga JA, Reinecke DM. Influence of auxin and gibberellin on in vivo protein synthesis during pea fruit development. *Plant Physiol*. 1996;112: 53-59.
37. Van Overbeek J, Conklin ME, Blakeslee AF. Factors in coconut milk essential for growth and development of *Datura* embryos. *Science*. 1941;94: 350.
38. Wang CF, You Y, Chen FLX, Wang J Wang JS. Adjusting effect of brassinolide and GA₄ on the orange growth. *Acta Agriculturae Jiangxiensis Universitatis*. 2004;5 – 22.
39. Huizen VR, Ozga JA, Reinecke DM. Influence of auxin and gibberellin on in vivo protein synthesis during pea fruit development. *Plant Physiol*. 1996;112: 53-59.

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