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The Effect of Salicylic Acid and Naphthalene Acetic Acid on Reducing Button Shedding in Dwarf Coconut (*Cocos nucifera* L.)

D Subhaktian, R Evizal*, H Novpriansyah, A Karyanto

Departement of Agrotechnology, Faculty of Agriculture University of Lampung, Indonesia

*Correspondence Email: rusdi.evizal@fp.unila.ac.id

Abstract. Button shedding in coconut (*Cocos nucifera* L.) is a major factor reducing yield, particularly during the dry season, when shedding levels can reach 70–80%. This research aimed to determine the effect of applying plant growth regulators, i.e. SA (salicylic acid) and NAA (naphthalene acetic acid), as well as their combination, in reducing button shedding in dwarf coconut cv Pandan Wangi. The research was conducted from December 2024 to April 2025 at PT. Great Giant Pineapple, Lampung Tengah, Indonesia. The research employed a non-factorial Randomized Complete Block Design (RCBD) consisting of a control and nine treatments: SA 2 mM with interval 1-weeks; SA 2 mM with interval 2-weeks; SA 2 mM with interval 1-months; NAA 0,5 ml/L with interval 1-weeks; NAA 0,5 ml/L with interval 2-weeks; NAA 0,5 ml/L with interval 1-months; SA and NAA with interval 1-weeks; SA and NAA with interval 2-weeks; and SA and NAA with interval 1-months. The treatments were applied on female flower cluster over a period of two months according to their respective intervals, starting from anthesis. Each treatment was replicated three times, resulting in a total of 30 experimental units. The data obtained were analyzed using homogeneity and additivity tests. Further analysis was conducted using Analysis of Variance (ANOVA), and significant differences among means were tested using the Honestly Significant Difference (HSD) test at the 5% significance level. The results indicated that the application of SA and NAA had a significant effect in reducing button shedding, although it inhibited fruit growth. However, an optimum concentration was found in the combination of SA 2 mM + NAA 0,5 ml/L, which reduced button shedding without inhibiting fruit development.

Keywords: Coconut, Button shedding, Naphthalene Acetic Acid, PGR, Salicylic Acid

1. Introduction

Plant family of *Arecaceae* (or *Palmaceae*) has 5 subfamilies includes and *Arecoideae* which has a total of 600 species from 27 genera including coconut (*Cocos nucifera* L.) under genus Cocos. Coconut which included in flowering plant group is a perennial palm, monoecious, and monocotyledons. It originates from the Pacific Ocean region, particularly Melanesia, Polynesia, and Southeast Asia including islands of Indonesia [1].

Coconut plantations hold significant economic, cultural, and social importance for communities across more than 80 tropical countries [2]. Being predominantly cross-pollinated, coconut exhibits high heterozygosity. They are classified into three main varieties: tall, dwarf, and hybrid [3]. Tall varieties can attain heights of 20–30 m and is distinguished by a sturdy stem. Flowering commences 5–7 years after planting, with productivity extending up to 80–100 years. This variety typically bears medium- to large-sized fruits in relatively high numbers per inflorescence, and is valued for producing copra of superior quality with a high oil content [4].

Dwarf varieties have attained commercial significance owing to their early bearing capacity, shorter stature, tender nut characteristics, and resistance to certain diseases. At 20 years of age, these palms typically reach a height of 8–10 m, begin flowering 3–4 years after planting, and exhibit a relatively short productive lifespan of 40–50 years. Owing to their predominantly self-pollinated nature, dwarf varieties are more homozygous than Tall palms [4]. They generally produce small to medium sized nuts and are believed to have originated from Tall varieties through either mutation or inbreeding. Dwarf coconut varieties are thought to have originated in Southeast Asia and underwent a process of domestication, most likely derived from the ancestral tall varieties. This domestication process involved mutations in flowering time genes, leading to self-pollination (autogamy), and in gibberellin biosynthesis, that affecting height [5].

Dwarf coconut button shedding, the premature dropping of young coconuts, can be caused by several factors including nutrient deficiencies, pest and disease infestations, environmental stress, and improper management practices [6]. Addressing these issues through proper fertilization, pest and disease control, and irrigation can help minimize button shedding and improve yield.

Plant hormones are fundamental endogenous regulators of plant growth and development, acting as signalling agents during flowering and fruiting processes. Plant hormones are classified into two groups: promoters and inhibitors. Promoters include auxins, gibberellins, and cytokinins that involved in growth and fruit development, while inhibitors that involved in fruit abscission include ethylene, jasmonic acid, and abscisic acid [7]. Activity of plant growth regulators depend on plant genotype, physiological phase of the plant, and also type, chemical structure, concentration of hormones [8].

Salicylic acid (SA) and naphthalene acetic acid (NAA) are chemical compounds function as plant growth regulators PGRs) which have physiological effect similar as endogenous phytohormones. PGRs can control plant growth and development including stimulate rooting, dormancy breaking, flowering, and control fruiting and ripening. SA can be produced endogenously by plants and plays a strong role in regulating plant growth, development, defense, and environmental stresses. NAA is a synthetic auxin that possesses the same physiological functions as indole-3-acetic acid (IAA) (Agudelo-Morales et al, 2021)[9]. Shahsavar et al. (2024) [10] reported that spraying SA and NAA on date palm flower clusters could reduce fruit fall and improve yield.

Applying exogenous plant growth regulators in coconut flower can help reducing the percentage of fruit drop before harvest, ultimately increasing the number of fruits per plant. This aligns with Kasturi Bai and Srinivasa [11] who reported successful control of button shedding in coconut by spraying salicylic acid (SA) on the inflorescence at the flowering stage, increasing the resistance of button compared to untreated inflorescences. This is also consistent with Malarvannan [6] who stated that application of naphthalene acetic acid (NAA) can prevent button shedding in coconut by reducing infestation by pests and diseases, which subsequently become secondary fungal infections.

2. Materials and Methods

Location of Research

This research was conducted at the Research and Development Experimental Farm of PT. Great Giant Pineapple, Terbanggi Besar, Lampung Tengah, Indonesia from December 2024 to April 2025. Geographically, the site is located at 04°48’22.841”S latitude and 105°10’44.426”E longitude, with an altitude of 51 m above sea level. The soil type is yellow-red podzolic. The average annual rainfall is 26,478 mm, with detailed annual rainfall data presented in Figure 1.

Tools and Materials

The equipment used included a backpack sprayer, measuring cup, hand counter, brix refractometer, digital caliper, and scale. Materials used were salicylic acid (SA) at 2 mM, naphthalene acetic acid (NAA) at 0.5 ml/L, water, and female flowers on the spathe of 4-year-old coconut plants.

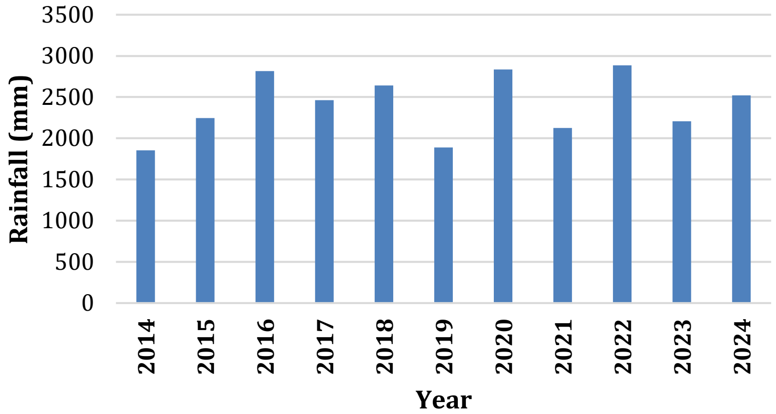

Figure 1. Annual rainfall 2014–2024 in the PT. Great Giant Pineapple area.

Research Methodology

The research used an experimental design of RCBD (Randomized Complete Block Design) consisted of 10 treatments with 3 replications. Each experimental unit comprised of 3 plants, amounting to a total of 30 plants. The treatments were: Control (P0), SA 2 mM interval 1 weeks (P1I1), SA 2 mM interval 2 weeks (P1I2), SA 2 mM interval 1 months (P1I4), NAA 0.5 ml/L interval 1 weeks (P2I1), NAA 0.5 ml/L interval 2 weeks (P2I2), NAA 0.5 ml/L interval 1 months (P2I4), SA+NAA interval 1 weeks (P3I1), SA+NAA interval 2 weeks (P3I2), and SA+NAA interval 1 months (P3I4). Applications were carried out for two months following each treatment interval.

The research procedure consisted of determining sample plants, preparing plant growth regulators, applying treatments to female flower, data observation and analysis. Sampling was based on criteria including plant age, spathe age (1 day after spathe opening), and number of female flower. The total overall sample plants was 30 and were tagged according to treatments.

Research Procedures

SA was prepared by weighing 1.10 g to be dissolved in 4 liters of water. NAA was prepared by weighing 2 g for 4 liters of water. SA and NAA powders were first dissolved in alcohol, then poured into 4 liters of water, then added one cap of Indostick as an adhesive agent for the plant growth regulators, and homogenized to obtain the solutions at the research doses.

Sprayer calibration was conducted before applying treatments to the spathe using the backpack sprayer. The calibration resulted in a spray volume of 200 mL within 13 seconds, which was used for application. Observations included recording, counting, monitoring phenomena in button shedding.

The number of button was counted using a hand counter to determine the exact number of button shedding. Careful inspection involved in observing possible symptoms of button shedding. Diameter of button and fruits were measured with a digital caliper. Coconut water was collected for volume measurement as well as for determination of brix value which were conducted by using hand refractometer. Most observations were made from 2 to 18 weeks after anthesis (waa).

Data Analysis

Data collected were the number of button shedding, acceleration of button shedding, percentage of button shedding with symptoms of pest, fungal, and natural cause, diameter of button and fruits, water coconut volume, and brix value. The formula for number of button shedding and acceleration of button shedding as presented in formula 1 and 2. Data were analyzed using ANOVA and further tested with the Honestly Significant Difference (HSD) using significance level of 5%.

$$\%\ \text{Button shedding} = \frac{\text{Initial number of female flowers} - \text{Final number of female flowers}}{\text{Initial number of female flowers}} \times 100\% \quad (1)$$

$$\% \text{ Acceleration of button shedding} = \sum_{i}^{n} \frac{(X_i - X_{i-1})}{T_i} \quad (2)$$

3. Results and Discussion

The results showed that the application of salicylic acid (SA) and naphthalene acetic acid (NAA) significantly affected the rate of button shedding in coconut, influencing number of button shedding, acceleration of button shedding, diameter of button and fruits, and water coconut volume. However, these treatments did not have a significant effect on button shedding with symptoms of pest, fungal, natural cause, or brix value.

3.1. Number of Button Shedding

Analysis of variance showed that treatments P3I4, P2I1, P2I4, P3I1, and P3I2 after 18 weeks after anthesis (waa) significantly reduced the percentage of button shedding compared to the control and SA-only treatments (P1I4, P1I2, P1I1), as presented in Table 1. The coconut fruit development from 1 to 18 week after anthesis were shown in the following figures. Fruit development in response to SA treatments is shown in Figure 2, that in response to NAA treatment in Figure 3, while the effect of combined treatment (SA+NAA) is in Figure 4.

NAA, either applied singly or combined with SA, significantly reduced button shedding in dwarf coconut cv Pandan Wangi, while SA alone did not. NAA application increases fruit production, fruit size, total yield per tree, and maturation without negatively affecting nutritional or organoleptic properties. NAA dramatically enhances harvest yield, fruit length and diameter, fruit weight, total sugars, total soluble solids (TSS), vitamin C content, and reduces fruit drop in guava. Auxins enhance carbohydrate translocation to fruits, enhance cell wall elasticity and induced fruit growth [12].

Table 1. Effect of salicylic acid and naphthalene acetic acid on the number of button shedding at 18 waa.

Treatments (code)	Button Shedding (%)
Control (P0)	81 b
Salicylic acid 2mM, interval 1 weeks (P1I1)	63 b
Salicylic acid 2mM, interval 2 weeks (P1I2)	67 b
Salicylic acid 2mM, interval 1 months (P1I4)	67 b
NAA 0.5 ml/L, interval 1 weeks (P2I1)	12 a
NAA 0.5 ml/L, interval 2 weeks (P2I2)	21 a
NAA 0.5 ml/L, interval 1 months (P2I4)	13 a
Salicylic acid+NAA, interval 1 weeks (P3I1)	13 a
Salicylic acid+NAA, interval 2 weeks (P3I2	14 a
Salicylic acid+NAA, interval 1 months (P3I4)	9 a
HSD 5%	33,44 *

Note: Means followed by the same letter are not significantly different based on the HSD test at 5%.

The number of fruit set observed under different treatments and observation times (initial fruit, 8 waa to 18 waa) is shown in Figure 5, with standard error of the mean (SEM) indicating that the treatments effect fruit set. In the control (P0), the initial fruit count was 41.33, which significantly dropped to 10.67 at 8 waa and 8.33 at 18 waa, indicating a high natural button shedding rate without plant growth regulator (PGR) treatment.

SA treatments at various intervals showed variable results. Treatment P1I1 was relatively ineffective in retaining fruit set compared to control, with initial fruit count of 37.00, decreasing to 15.33 at 8 waa and 14.00 at 18 waa. NAA treatments also varied; P2I1 showed better fruit set with initial 40.67 fruits, decreasing to 36.00 at 8 waa and sustained until 18 waa. The combination of SA 2 mM + NAA 0.5 ml/L at different intervals also showed an effective effect. Treatment P3I4 was relatively effective in maintaining fruit, with initial fruit count of 44.67, decreasing slightly to 42.00 at 8 waa and 41.00 at 18 waa.

The combined SA+NAA treatments consistently showed lower button shedding rates. This supports findings by Davies and Zalman [13] that auxins and gibberellins are applied to control fruit fall in citrus and enhance fruit quality. SA application results align with Chen and Dekkers [14] who stated that SA inhibits biosynthesis and function of jasmonic acid (JA), a growth regulator important in young fruit abscission. Therefore, SA application in sweet orange and grapefruit effectively controls young fruit drop and increases fruit retention. Lima and Davies [15] also noted that the problem of fruit drop may be reduced by optimizing water and nutrients for susceptible varieties and applying plant growth regulators.

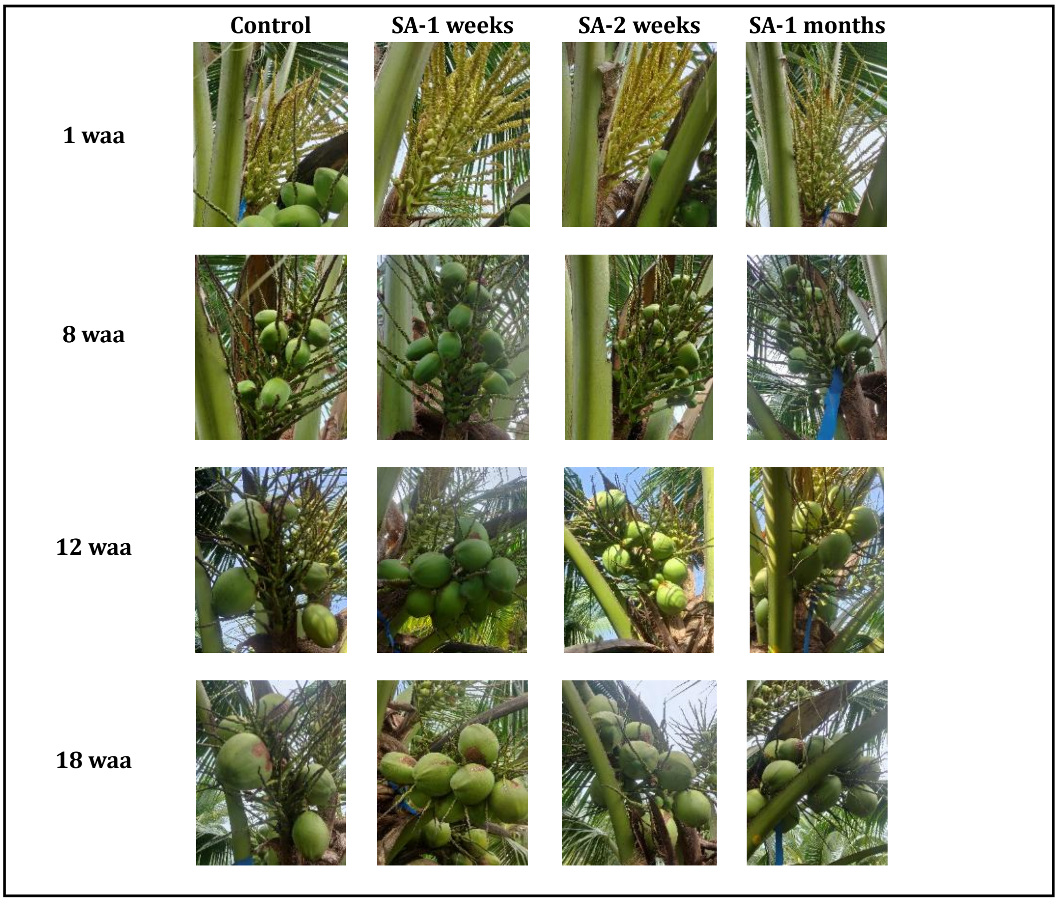

Figure 2. Fruit performance of control compared SA with 3 intervals application.

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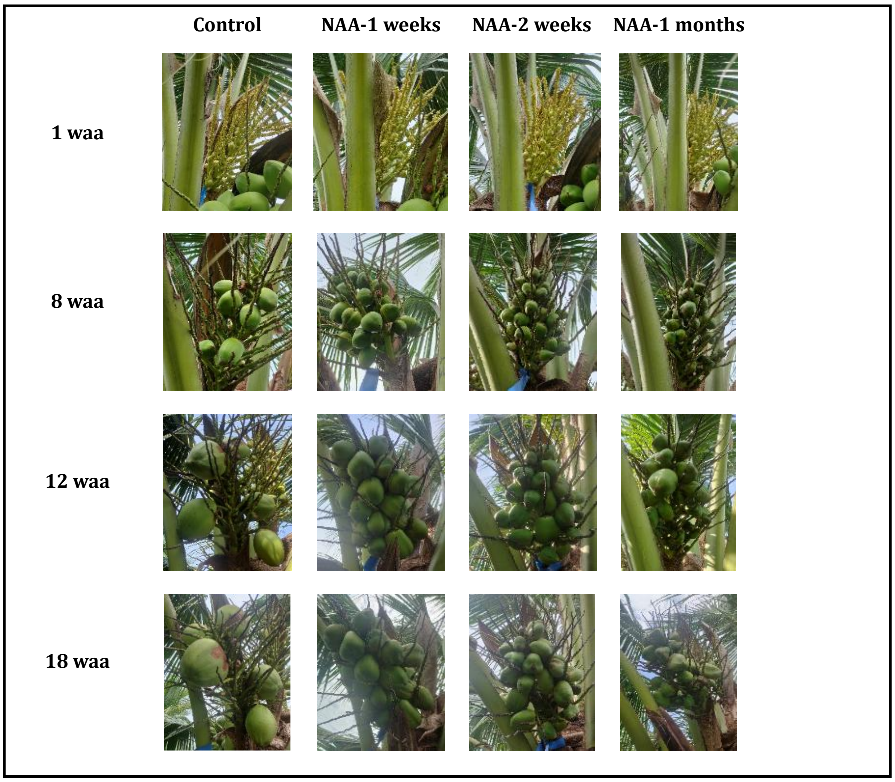

Figure 3. Fruit performance of control compared NAA with 3 intervals application.

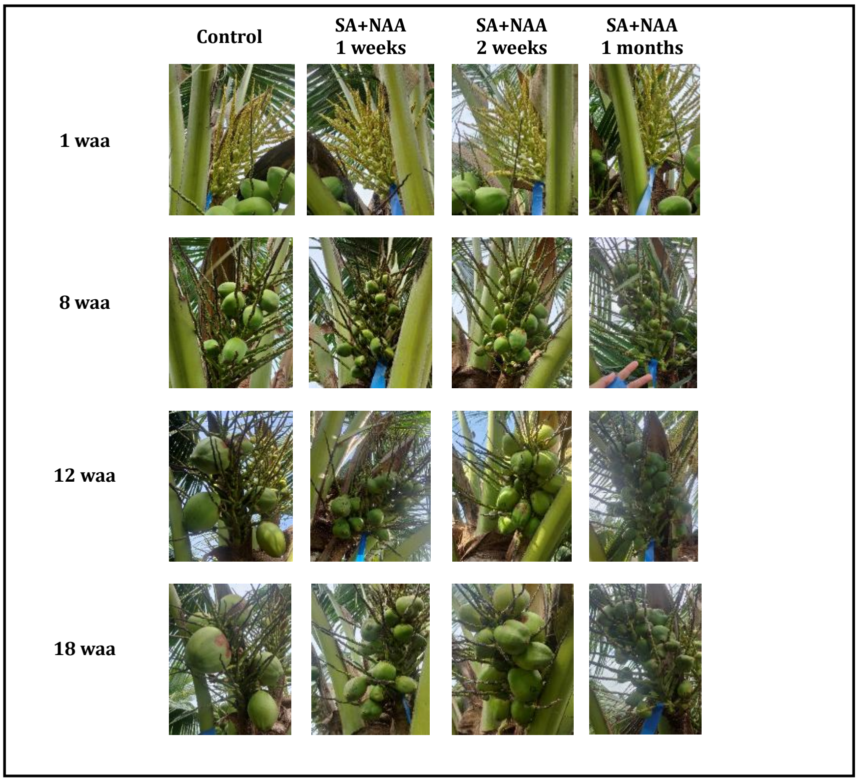

Figure 4. Fruit performance of control compared SA+NAA with 3 intervals application.

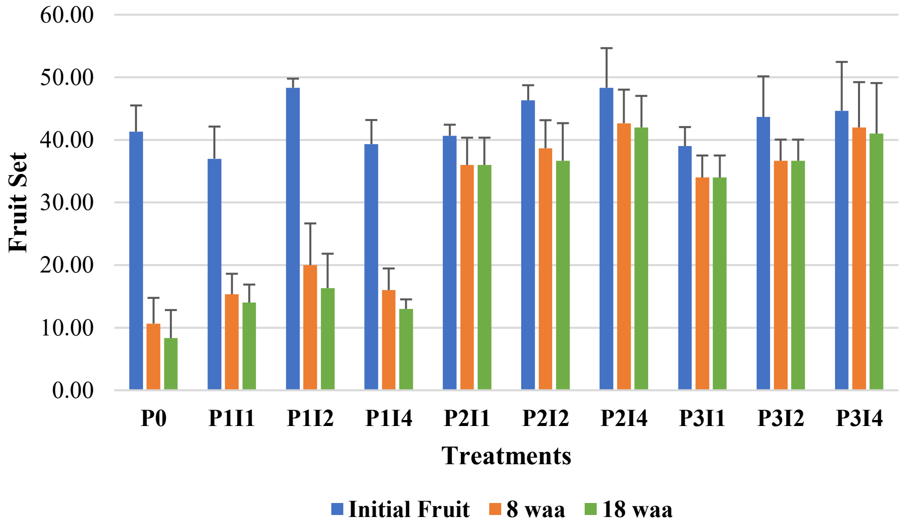

Figure 5. Effect of salicylic acid and naphthalene acetic acid on the average number of fruit set at 8 waa and 18 waa.

3.2. Acceleration of Button Shedding

Based on the results of the analysis of variance, the acceleration of button shedding in each treatment on D2, D4, D5, D6, D7, D8, D9, D10, D12, D13 is not significantly different as shown in Figure 6. D3, D11, D14 showed a significant acceleration of button shedding. i.e. salicylic acid + NAA interval 1 weeks, salicylic acid 2mM interval 2 weeks, and control as shown in Table 2. Data analysis of treatments using the combination of plant growth regulators (SA+NAA) showed a significant effect compared to the control. This supported by Hagagg *et al*. [16] who described SA as a natural phenolic compound in plants that regulates various physiological and biochemical processes, including photosynthesis, nitrogen metabolism, proline metabolism, antioxidant defense, and plant-water relations.

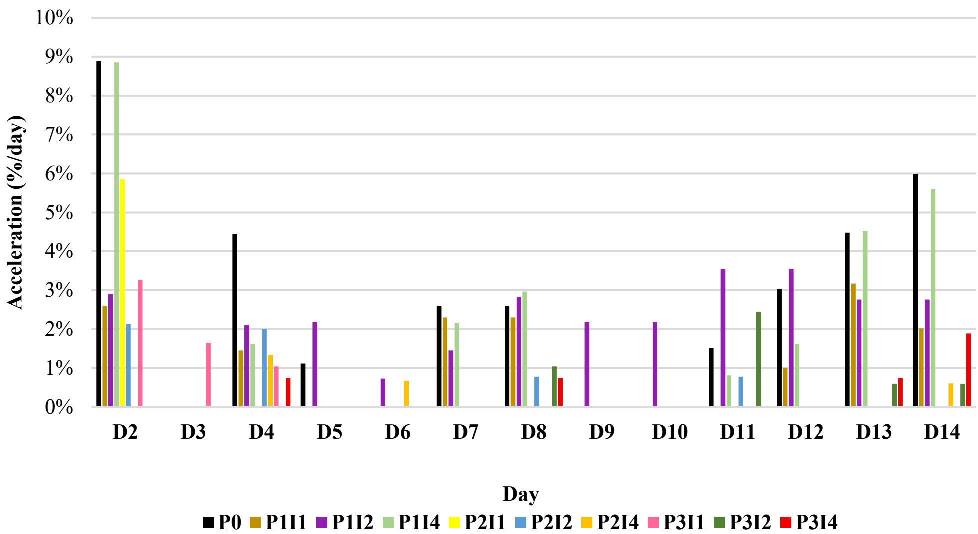

Figure 6. Effect of salicylic acid and naphthalene acetic acid on the average acceleration of button shedding at day 1 to day 14 after anthesis.

The application of NAA can inhibit gene expression and the activity of enzymes (cellulase and pectinase) responsible for cell wall weakening in the abscission zone. This aligns with the findings of Zhang *et al*. [17] who reported that exogenous application of NAA on peach fruit increased the level of IAA (natural auxin) and significantly decreased the level of ABA during the fruit expansion stage. In general, this combined treatment can reduce stress and jointly decrease abscission signaling, especially when applied at the appropriate timing and dosage. SA is beneficial for maintaining fruit firmness and delaying fruit senescence by inhibiting ethylene biosynthesis [18]. This is consistent with Yuan and Li [19] who stated that NAA, a synthetic auxin, reduces pre-harvest fruit drop and enhances fruit softness. Maurya *et al*. [20] observed that NAA increased the size and weight of date fruits and delayed their ripening.

Table 2. Effect of salicylic acid and naphthalene acetic acid on the average acceleration of button shedding at day 3, day 11, and day 14 after anthesis.

Treatments	Acceleration (%)/Day		
	Day 3	Day 11	Day 14
Control	0.00 a	1.33 abc	6.33 c
Salicylic acid 2mM, interval 1 weeks	0.00 a	0.00 a	2.00 ab
Salicylic acid 2mM, interval 2 weeks	0.00 a	3.33 c	2.66 abc
Salicylic acid 2mM, interval 1 months	0.00 a	0.67 ab	5.33 bc
NAA 0.5 ml/L, interval 1 weeks	0.00 a	0.00	0.00 a
NAA 0.5 ml/L, interval 2 weeks	0.00 a	0.67 ab	0.00 a
NAA 0.5 ml/L, interval 1 months	0.00 a	0.00 a	0.66 a
Salicylic acid+NAA, interval 1 weeks	1.66 b	0.00 a	0.00 a
Salicylic acid+NAA, interval 2 weeks	0.00 a	2.33 bc	0.66 a
Salicylic acid+NAA, interval 1 months	0.00 a	0.00 a	1.66 ab
BNJ 5%	1.38 *	2.27 *	3.94 *

Note: Means followed by the same letter are not significantly different based on the HSD test at 5%.

3.3. Percentage of Button Shedding with Symptoms of Pest, Fungal, and Natural Cause

The internal parts of the button shedding on the spathe were examined, as shown in Figure 7. The results of percentage of button shedding with symptoms of pest, fungal, natural cause show that on average each treatment that is dominated by natural cause, as shown in Figure 8. In symptomatic pest shedding, control treatment exhibits the highest drop, while the lowest drop was in the P1I1 and P1I2 treatments. In symptomatic fungal shedding, the highest drop was in the treatment of control, while the lowest drop was in the P1I1 and P1I4 treatments. In symptomatic natural shedding, the highest drop was in the treatment of control, while the lowest drop was in the P1I4 treatment.

Button shedding caused by pests occurs when pests attack the reproductive parts of the plant and damaging the tissue and inhibiting fertilization. Fungal symptoms on button cause necrosis and premature decay, which also inhibit fertilization and lead to abscission before fruit development. Natural abscission is a plant’s inherent mechanism to adjust the number of fruits it can sustain according to physiological conditions, nutrient availability, and environmental stress. This aligns with Bernier *et al*. [21] who stated that flowering and fruit set in fruit plants are influenced by environmental growth factors and endogenous plant factors such as humidity, nutrient status, and growth hormones. The environmental factors with the greatest impact on fruit set are air temperature, humidity, rainfall, and light intensity [22].

(a) (b) (c)

Figure 7. Symptoms: (a) pest damage, (b) fungal infection, and (c) natural abscission.

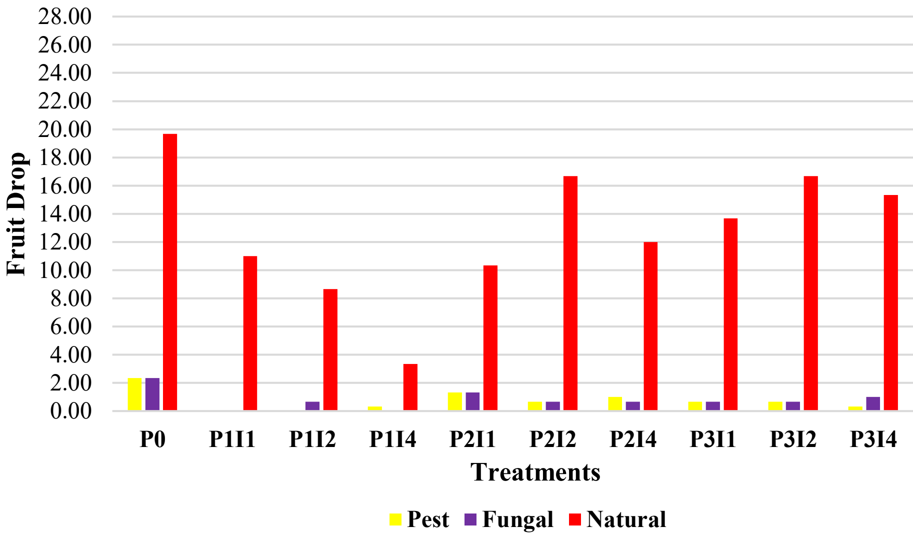

Figure 8. Effect of salicylic acid, naphthalene acetic acid, and their combination on the average percentage of button shedding with symptoms of pest, fungal, and natural cause from 2 waa to 18 waa.

3.4. Diameter of Button and Fruits

Observations at 11 waa, P1I2 treatment exhibited a significantly higher diameter increment compared to other treatments. Treatments P3I1, P3I2, P3I4 showed a significantly lower diameter increase compared to other treatments. At 14 waa, P0 treatment caused a significantly higher diameter increase compared to other treatments. The P2I1 treatment experienced a significantly lower diameter increase compared to other treatments. At 17 waa, P1I2 treatment showed a significantly higher diameter increase compared to other treatments. The P3I4 treatment caused a significantly lower diameter increase contrasted to other treatments is shown in Table 3.

The application of plant growth regulators in this research, particularly NAA, showed a negative response on fruit development, which is suspected to be due to excessive dosage or overly frequent application. According to Turak *et al.* [23], as the application dose increases, the rate of thinning also increases, however higher doses cause damage to leaves and result in smaller fruit size. Fruit drop and disrupted growth can reduce water and nutrient uptake and transport to the fruit. The retention or abscission of flowers and fruits is influenced by a combination of endogenous and environmental factors [24].

Soil properties and characteristics, including physical, chemical, and biological traits, influence the soil's ability to support plant growth. Soil characteristics at PT. Great Giant Pineapple showed a low level of total N, P, K, cation exchange capacity, C organic, soil pH which need a good soil nutrient management for coconut [25]. Moreover, the use of plant growth regulators such as NAA is indeed beneficial in regulating growth and preventing fruit drop. Improper application of NAA can accelerate fruit ripening, increase pre-harvest fruit drop in apples, and the size fruit development [26].

Table 3. Effect of Salicylic Acid and Naphthalene Acetic Acid on the diameter of button and fruits.

Treatments	Diameter (mm)		
	11 waa	14 waa	17 waa
Control	65.85 a	87.36 ab	96.24 abc
Salicylic acid 2mM, interval 1 weeks	67.64 a	88.00 ab	96.96 ab
Salicylic acid 2mM, interval 2 weeks	71.80 a	92.68 a	106.82 a
Salicylic acid 2mM, interval 1 months	71.56 a	88.97 ab	101.93 ab
NAA 0.5 ml/L, interval 1 weeks	61.76 a	66.25 ab	72.98 abc
NAA 0.5 ml/L, interval 2 weeks	57.93 a	62.78 ab	74.93 abc
NAA 0.5 ml/L, interval 1 months	55.00 a	65.43 ab	71.01 abc
Salicylic acid+NAA, interval 1 weeks	60.44 a	67.62 ab	69.91 bc
Salicylic acid+NAA, interval 2 weeks	50.12 a	59.55 b	70.76 abc
Salicylic acid+NAA, interval 1 months	51.15 a	59.22 b	60.64 c
HSD 5%	22.25	30,87 *	35.49 *

Note: Means followed by the same letter are not significantly different based on the HSD test at 5%.

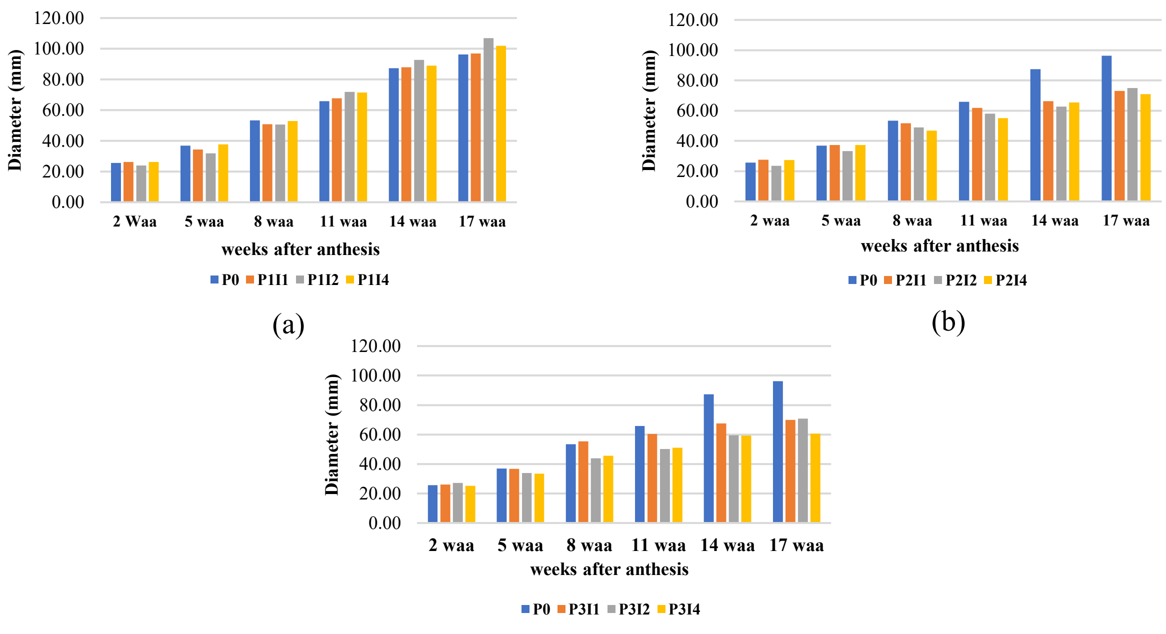

Figure 9. Effect of treatment: (a) SA compared to control, (b) NAA compared to control, and (c) SA+NAA compared to control on diameter from 2 waa to 17 waa compared to control.

The effect in diameter of button and fruits showed that all treatments caused an increase in diameter from previous observations starting at 2 waa to 8 waa. After 8 waa, but treatments containing NAA

(P2I1, P2I2, P2I4, P3I1, P3I2, and P3I4) showed a lower increment. Treatments SA (P0, P1I1, P1I2, P1I4) caused better increment as shown in Figure 9.

Deficiencies in nutrient uptake of B, N, P, K, Ca, Mg, and Zn in coconut plants greatly affect fruit production both quantitatively and qualitatively. This aligns with Kamalakshiamma *et al*. [27] who reported that boron deficiency is common in coconut trees, causing malformations in various leaf and fruit types and shapes, leading to stunted growth and low productivity. Jucoski *et al.* [28] noted that excess Fe in leaf tissues may cause nutrient imbalances in trees, resulting in deficiencies of K, Mg, P, and Ca.

3.5. *Water Coconut Volume*

Observations Treatment SA interval 1 months produced a significantly higher water coconut volume, but not significantly different with control, SA interval 1 weeks, SA interval 2 weeks, and SA interval 1 months, as presented in Figure 10. The results of water coconut volume the highest water volume was found in SA interval 1 months with an average of 400 ml, followed by treatment SA interval 2 weeks with an average of 380 ml, and the lowest average water volume was found in NAA interval 2 weeks with an average water volume of 55 ml. Water coconut volume due to small diameter of fruits, is shown in Table 3.

Plant hormones include auxins, gibberellins, and ethylene are endogenous factors that regulate abscission organs, including button and fruits. Auxin application promotes cell division and expansion [29]. Accelerated cell expansion increases fruit size and its capacity to water volume and metabolites, however inappropriate dosages can cause abnormal fruit development.

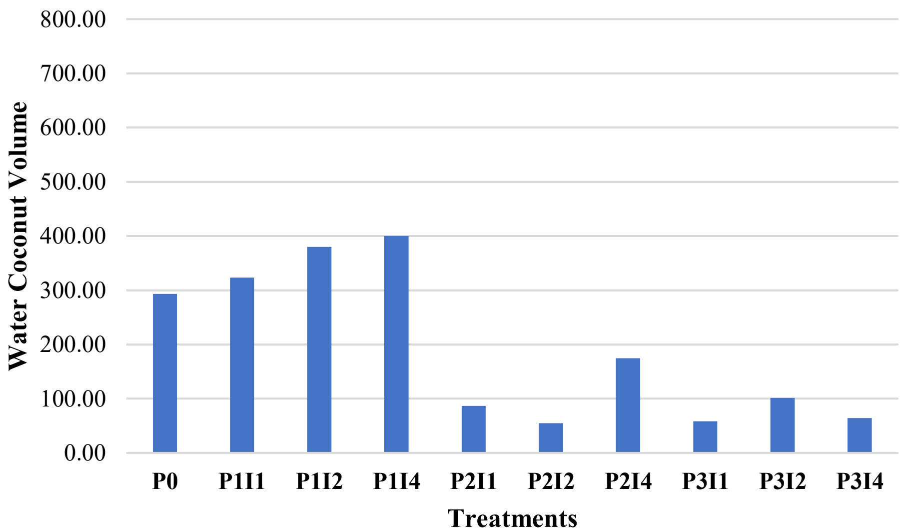

Figure 10. Effect of salicylic acid and naphthalene acetic acid on water coconut volume at 18 waa.

3.6. *Brix Value*

Observations The results of the brix value in coconut fruits was observed an average 4.21, but not significantly difference with control, as presented in Figure 11. The coconuts that were measured for brix value were 4 months old. Tender coconut at 4 months old reaching the threshold of 4 - 4,5 brix value [30]. The highest sugar content occurs at 7 – 8 months old with brix value of 5.07 – 5.18, after which the brix value decreases.

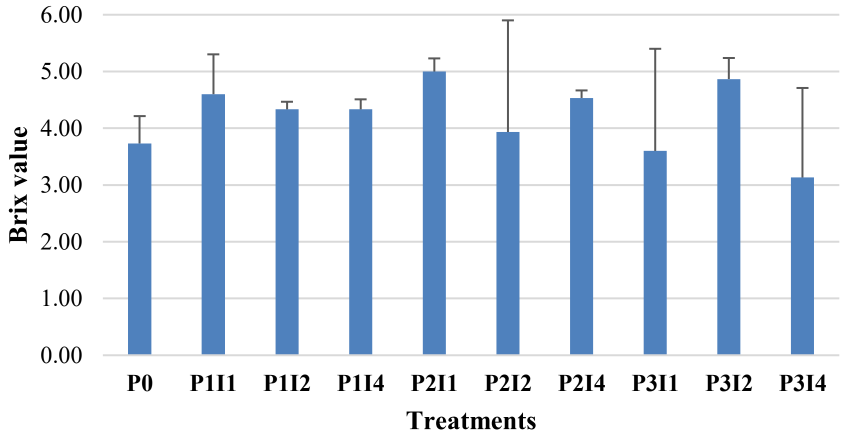

Figure 11. Effect of SA and NAA acid on brix value in coconut fruits at 18 waa.

4. Conclusions

The application of salicylic acid (SA) and naphthalene acetic acid (NAA) effectively suppressed button shedding in coconut, thereby increasing the number of fruit set. The treatments showed a significant effect on the number of button shedding, acceleration of button shedding, diameter, and water coconut volume. However, these treatments did not significantly affect brix value or button shedding with symptoms of pest, fungal and natural cause. The optimum concentration to reduce button shedding in coconut was found at the treatment with NAA (0.5 ml/L) interval 1 months and the combination treatment of SA 2 mM + NAA 0.5 ml/L interval 1 months. Both treatments effectively suppressed button shedding without inhibiting fruit development showed by diameter and water volume at coconut fruit.

5. Acknowledgement

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