



Enhancing Flowering and Nut Development of Tacunan Dwarf Coconut (*Cocos nucifera* L.) through Plant Growth Regulators

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Abstract: Coconut production in Central Visayas, Philippines, is increasingly constrained by climate variability, recurrent drought, and alkaline soils that disrupt the reproductive cycle and limit yield by reducing spathe emergence, flower development, flowering time, and nut retention. This study evaluated plant growth regulators (PGRs) for enhancing reproductive performance in the Tacunan dwarf coconut (*Cocos nucifera* L.). Using a randomized complete block design, four treatments were applied to 10-year-old palms: control, auxin (100 ppm), ethylene (100 ppm), and combined auxin–ethylene (50 ppm each). Treatments produced distinct responses. Auxin accelerated spathe emergence by 16 days and raised female flower production to 90.50 per palm by week 8, yielding earlier and more prolific flowering. Ethylene reduced flower number to 58.16, but shortened time to flowering to 88.75 days and improved nut retention to 70.50 nuts per month, versus 46.33 in the control. The combination treatment gave intermediate results, indicating responses constrained by dosage or hormonal antagonism. Button shedding and delayed flowering, typically induced by alkaline soil (pH 7.98) and drought, were partially mitigated by auxin and ethylene, leading to enhanced cell enlargement and regulation of pollination. Although the four-month duration was insufficient to assess effects on nut size and weight, the results provide novel empirical evidence that PGR interventions improve coconut reproductive performance and establish a baseline for long-term strategies to stabilize coconut yields under stress-prone conditions.

Keywords: Tacunan dwarf coconut; auxin; ethylene; reproductive performance; alkaline soil

1. Introduction

Coconuts have become increasingly popular recently due to the growing promotion of virgin coconut oil, coconut water, and inflorescence sap as nutritious and health-friendly products [1]. The perennial nature of palms hinders successful breeding efforts, as does their greater level of heterozygosity, their lengthy juvenile period, the need for a wider area, and the need for more time for testing. Mutagenesis combined with molecular-marker selection has been applied to broaden genetic variation and accelerate improvement in other ornamental and horticultural species [2]. Thus, the quantity of female flowers within an inflorescence plays a key role in determining coconut fruit set [3, 4]. The Sri Lanka Green Dwarf (SLGD) is self-pollinating and is sensitive to abiotic

stress. Hence, SLGD was crossed with tall coconut varieties (Sri Lanka Tall) to improve fruit set even when the number of female flowers was limited [5]. However, the dwarf coconut has the advantage of having a shorter trunk, which can make harvesting less time-consuming [6]. Coconuts may grow in a variety of soil types, from sandy to clay. It does, however, favor rich, well-drained soils that can hold a lot of water and are at least 75 cm deep. The palm can withstand soil pH levels between 5.0 and 8.0. However, a pH range of 5.5 to 6.5 is optimal for growth [7]. In the study of [8], the soils in Barili, Cebu, range in color from dark brown to yellowish brown, have a high clay content (46–70%), have a water-holding capacity (>40%), and are hard when dry but plastic and sticky when wet. Due to their extremely high CaCO_3 content (>60%), moderate to high CEC (21–53 meq/100 g), and high base saturation (>50%), the soils have an alkaline pH (7.5).

Based on the current findings, the production of key non-food and industrial commercial crops in Cebu totaled 45,236.93 metric tons in the first semester of 2024, representing a 60.48% decline, according to [9]. Severe impacts on coconut yield were associated with declines in nut quality, soil fertility, seasonal patterns, and labor requirements, while moderate impacts were linked to extreme weather events, water shortages, and heat stress [10]. The use of plant growth regulators (PGRs) can potentially improve flowering and nut development in coconuts under drought stress. In the study of [5], Sri Lanka Green Dwarf palms experienced a 26% to 46% reduction in female flower production due to intense water shortage during the -2 developmental stage, compared to palms that were not exposed to stress, regardless of whether other stages encountered heat or water. To lessen the negative effects, the current study will explore the use of two PGRs, auxin and ethylene. Auxins (Indole-3-Acetic Acid, IAA) are known to influence flower initiation and fruit development and may promote fruit setting and nut growth in coconuts. Auxin regulates multiple aspects of plant growth and development, such as seed germination, stem elongation, flower initiation, and fruit expansion [11]. Transcriptome analysis in oil palm has shown that auxin treatments can induce parthenocarpic fruit sets, with candidate genes identified [12]. Beyond oil palm, plant growth regulators have enhanced growth, yield, and propagation across diverse horticultural crops, including gibberellic and salicylic acid treatments in kale [13], indole-3-butyric acid and gibberellic acid in caladium [14], and benzyladenine and indole-3-butyric acid in cactus [15]. However, its direct effect on coconut nut retention and female flower production has not been established. Ethylene releasers, such as Ethephon, can help synchronize flowering and promote early fruit maturity. In fruit crops, ethylene plays a pivotal role in controlling fruit sets at distinct stages of the flower-to-fruit transition [16]. Additionally, exogenous ethylene application accelerated oil palm fruit ripening, increased oil yield, and decreased free fatty acids [17], but reproductive synchronization has not been systematically tested in coconut. These limitations highlight the need for targeted research on PGRs in coconut reproductive biology, which this study aims to address.

The Tacunan dwarf coconut variety will be used as a test crop in the experiment. It begins fruiting early, often producing its first bunches with nuts nearly touching the ground in less than two years under optimal conditions. On average, each palm yields around 94 nuts annually, with the potential to reach up to 204 nuts per year, and each nut contains more than 250 grams of copra [7]. Therefore, this study aims to evaluate the effects of plant growth regulators, specifically auxin and ethylene, on the flowering behavior and nut development of the Tacunan dwarf coconut variety. By exploring their influence on reproductive growth, the research seeks to determine whether PGRs can help overcome soil-related constraints and improve coconut productivity in stress-prone areas like Barili, Cebu, and during prolonged droughts, when rainfall levels drop by over 60%.

2. Materials and Methods

2.1 Soil and Climate Baseline Data Collection

Composite samples were collected across the experimental area before treatment application to establish baseline soil conditions. The soils were air-dried, sieved, and sent to the Department of Agriculture in Tacloban City for analysis. Composite samples (0–30 cm depth) were analyzed for pH, organic matter, and available macronutrients (N, P, K) following standard protocols. Data on rainfall and temperature during the study period were obtained from [18], based on records from the nearest weather station in Cebu.

2.2 Treatments and Experimental Design

The study was conducted at the coconut farms of Cebu Technological University–Barili Campus, located in Barangay Kalubihan, Barili, Cebu. The PCA VII identified the coconut variety as Tacunan dwarf. A Randomized Complete Block Design (RCBD) was employed, incorporating two plant growth regulator (PGR) treatments and a control group. There were two samples per treatment with four replications. PGRs were applied in various types and combinations to examine their effects on flowering, nut development, and overall yield. Treatments were administered both individually and in combination. The coconut trees selected were at bearing age, approximately 10 years old. The study was conducted from July 09 to November 09, 2025. The concentrations selected for this study were guided by prior research and experimental reasoning. Applying auxin at 100 ppm enhanced fruit set in oil palm female inflorescences [12], providing a clear benchmark for perennial palms. Although no published work has reported the use of 100 ppm ethylene in coconut, this level was adopted as a practical reference based on evidence of ethylene efficacy in annual crops [16] and to maintain consistency with the auxin treatment. In addition, the combined application of auxin and ethylene at 50 ppm each was designed to explore possible synergistic effects while reducing the risk of hormonal imbalance. Overall, the chosen concentrations are biologically relevant, supported by literature, and feasible for field application, while also addressing the existing gap in coconut reproductive biology.

The treatments include:

- t1- control (mineral water)
- t2- Auxin (naphthalene acetic acid) at 100 ppm
- t3- Ethylene (2-chloroethylphosphonic acid) at 100 ppm
- t4- Auxin at 50ppm + Ethylene at 50ppm

2.3 Application of Treatments

The application process begins by drenching the soil with 1 L of auxin solution, depending on the treatment. One week later, ethylene of a 500 ml solution was sprayed onto the foliage and reapplied every two weeks thereafter. Auxin (NAA) application via soil drenching ensures systemic uptake through the root system. According to [19], soil drench applications of auxin significantly improved overall root quality in ornamental perennial plants. Ethylene (2-chloroethylphosphonic acid) is a gaseous plant hormone; in practice, it is applied as ethephon via foliar spraying to ensure direct leaf contact. This allows rapid absorption and decomposition into ethylene gas within leaf tissues, quickly triggering physiological responses such as flowering, fruit ripening, or abscission. Foliar application of ethylene promoted early flower induction and increased the number of flowers in mungbean [20]. Auxin and ethylene were applied only during the initial two months of the study. The subsequent two months were allocated for data monitoring and observation.

2.4 Data Gathering Procedures

Before treatment application, the inflorescence development of each ten-year-old coconut tree was documented to establish a baseline. Following the application of plant growth regulators, developmental progression was monitored and evaluated against the initial stage, using the chart of critical coconut bunch development stages documented during the study and based on references [5, 21]:

The following data were collected:

2.4.1 The Number of Days to First Visible Spathe Emergence

This metric records the number of days from a defined starting point (e.g., the visible emergence of the youngest leaf in the crown or the initiation of the inflorescence primordium if microscopic observation is feasible) until the spathe (the boat-shaped, protective sheath enclosing the developing inflorescence) becomes clearly visible, protruding from the leaf axil. At this stage, the spathe is typically green and tightly enclosed, but its distinct form is apparent.

2.4.2 The Number of Days to Flower (from spathe emergence to spathe opening)

This measurement refers to the number of days from the initial observation of the spathe emergence (as described above) until the spathe fully splits open longitudinally, revealing the individual flower-bearing

branches (rachillae) within. This splitting marks the beginning of the anthesis or flowering period, as the male flowers typically open and shed pollen shortly after. This stage indicates readiness for pollination.

2.4.3 The Number of Female Flowers per Tree per Week

This parameter was assessed by directly counting the pistillate (female) flowers present on each emerged inflorescence. The female flower, often referred to as a "button" in its immature stage, is a small, typically spherical to subglobose body, approximately 1-2.5 cm (0.4-1 inch) in diameter, with a distinct resemblance to a miniature coconut.

2.4.4 The Number of Nuts per Tree per Month

This parameter was assessed by counting the total number of mature and developing nuts within each fruiting bunch on the tree. A "fruiting bunch" refers specifically to the inflorescence during its fruit-setting stage, which was previously termed "inflorescence" at the flowering stage. Data was recorded at two-week intervals.

2.4.5 The Nut Size at Harvest (cm)

For both young (6–9 months after spathe emergence) and mature (11–12 months after spathe emergence) coconuts, the equatorial diameter of each harvested nut was measured using a flexible tape. This involves recording the widest horizontal span across the nut taken at its midpoint and perpendicular to the vertical axis while the nut remains enclosed in its husk.

2.4.6 The Single Nut Weight (g) at harvest

The weight of each harvested nut was determined immediately upon collection using a calibrated electronic balance and recorded to the nearest 0.1 gram. This measurement will include the entire nut, with its husk intact, consistent with other harvest assessments.

2.4.7 Data Analysis

Analysis of Variance (ANOVA) was used to analyze the data gathered using the Statistical Tool for Agricultural Research (STAR). A post hoc test (Tukey's HSD) was utilized to compare treatment means and identify the best-performing techniques.

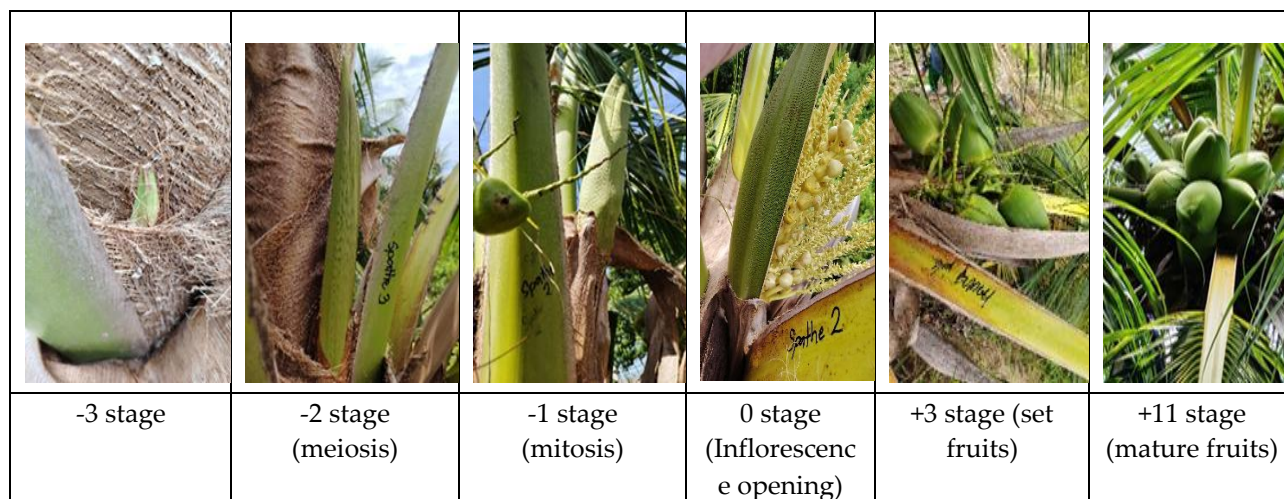


Figure 1. Critical Development Stages of the Coconut Bunch

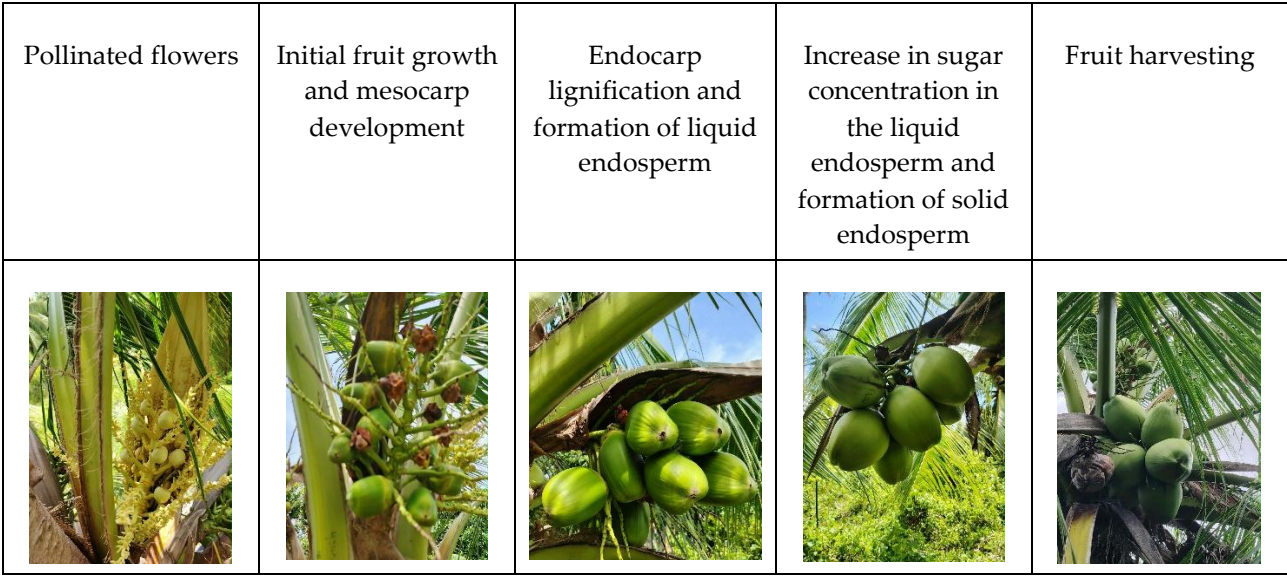


Figure 2. Development Stages of the Nut

3. Results and Discussion

3.1 Soil Chemical Properties and Climatic Conditions (July-November 2025)

Table 1. Analysis on soil chemical properties and the climatic conditions at the experimental site, barili, cebu, during July-November 2025.

Parameter	Value	Unit
pH	7.98	-
Organic Matter	2.06	%
Available nitrogen	0.10	%
Total Nitrogen	0.12	%
Available Phosphorus	7.55	mg/kg
Exchangeable Potassium	0.28	cmol/kg
July 2025 (Rainfall)	210	mm
August 2025 (Rainfall)	185	mm
September 2025 (Rainfall)	195	mm
October 2025 (Rainfall)	220	mm
November 2025 (Rainfall)	160	mm
July-November (mean temperatures)	28.5	°C

Results revealed that the soil is alkaline (pH 7.98), with low nutrient availability, fluctuating rainfall (160–220 mm/month), and elevated temperature (28.5 °C). These findings further confirm that coconut plantations in the area are subject to environmental stress. Such conditions tend to intensify button shedding and reduce spathe emergence, flowering time, and development, and nut set. Application of PGRs (auxin and ethylene) mitigates the adverse effects of drought [22]. Although previous studies demonstrated that ethylene signaling pathways are centrally involved in plant adaptation to abiotic stresses such as drought, salinity, and alkaline conditions [23], direct applications of ethylene and auxin on coconut palms are limited under alkaline soil and drought stress conditions. The present study provides novel empirical evidence by assessing auxin and ethylene levels in coconut palms grown in alkaline soil under drought stress.

3.2 Reproductive Cycle

3.2.1 Average Number of Days to First Visible Spathe Emergence

The application of plant growth regulators significantly influenced the number of days to the first visible spathe emergence in Tacunan dwarf coconut (Table 2). Visibly emerging spathes were recorded as being in the -3 stage, counted from the day of emergence.

Table 2. Average number of days to first visible spathe emergence of tacunan dwarf applied with plant growth regulators

Treatment	Average Number of Days to First Visible Spathe Emergence
t ₁ - water only	22.16 ^b
t ₂ - auxin alone (100 ppm every two weeks)	16.00 ^a
t ₃ - ethylene alone (100 ppm every two weeks)	18.66 ^{ab}
t ₄ - combination (100 ppm every two weeks)	16.83 ^{ab}
%CV	14.69

Note: Means with different letters are significantly different at 5% level ($p < 0.05$)



Figure 3. Image of the spathe at the -3 stages of emergence.

Among the treatments, auxin alone (t₂) recorded the earliest spathe emergence, averaging 16.00 days, and was statistically faster than the water-only or control (t₁), which had the longest emergence time at 22.16 days. Treatments involving ethylene alone (t₃) and the combination of auxin and ethylene (t₄) showed intermediate effects, with means of 18.66 and 16.83 days, respectively. The outcomes correspond to those of [24], where treatments with NAA induced more than 95% of bunch formation, with 300 ppm NAA reaching 100% bunch formation. Additionally, auxin plays an important role in stimulating cell expansion and stem growth [25]. The study suggests that while auxin alone was most effective in accelerating spathe emergence, combining it with ethylene or using ethylene alone may offer moderate benefits. Overall, the findings highlight auxin's potential as a key regulator in promoting earlier reproductive development in coconut palms.

3.2.2 Average Number of Days to Flower

Table 3 summarizes the average number of days to flower, measured from spathe emergence to spathe opening. The results revealed clear differences among treatments.

Table 3. Average number of days to flower of tacunan dwarf applied with plant growth regulators.

Treatment	Average Number of Days to Flower
t ₁ - water only	97.75 ^a
t ₂ - auxin alone (100 ppm every two weeks)	89.88 ^b
t ₃ - ethylene alone (100 ppm every two weeks)	88.75 ^b
t ₄ - combination (100 ppm every two weeks)	91.38 ^{ab}
%CV	3.84

Note: Means with different letters are significantly different at 5% level ($p < 0.05$).

Ethylene alone produced the shortest time to flower at 88.75 days, which was markedly earlier compared to the control (97.75 days). Auxin alone also promoted earlier inflorescence at 89.88 days, showing only a slight difference from the ethylene treatment but still significantly earlier than the control. The combination of auxin and ethylene resulted in 91.38 days to flower, which was lower than the control but not as pronounced as the individual applications of auxin or ethylene. This result coincides with the study of [26], wherein, in 1968, pineapple plants were induced to flower using 2-chloroethylphosphonic acid (ethephon), an agent that releases ethylene and successfully promotes earlier flowering. Historically, whether through natural or artificial induction of flowering or its suppression, ethylene has remained the central regulator. At present, large commercial plantations routinely apply ethephon or ethylene weekly to synchronize pineapple production.

3.2.3 Average Number of Female Flowers per Tree per Week

Table 4 shows the average number of female flowers per tree per week for Tacunan dwarf coconuts treated with plant growth regulators. Some of the older spathes were recorded at the -1 stage (mitosis), which opened rapidly during the early weeks. Others were at the -2 stage (meiosis), while the remaining were at the -3 stage. Each spathe stage requires a different number of days or weeks before opening [27], which explains the variation in the number of female flowers observed. The timing of spathe opening influences this variation, the number of female flowers present, the transitioning of flowers to immature nuts, and the extent of button shedding [28, 29].

Table 4. Average number of female flowers per tree per week of tacunan dwarf applied with plant growth regulators

Treatment	Average Number of Female Flowers per Tree per Week								
	W0	W2	W4	W6	W8	W10	W12	W14	W16
t1- water only	32.33	35.66 ^b	55.00	56.33	83.66 ^{ab}	63.88 ^a	39.50 ^a	68.88 ^{ab}	64.50 ^{ab}
t2- auxin alone	31.50	55.50 ^a	60.66	63.33	90.50 ^a	52.50 ^{ab}	33.12 ^{ab}	73.25 ^a	71.75 ^a
t3- ethylene alone	32.33	39.83 ^b	52.83	43.16	58.16 ^c	36.50 ^b	25.12 ^b	60.12 ^b	58.12 ^b
t4- combination	27.00	43.50 ^b	54.83	44.16	64.00 ^{bc}	41.50 ^{ab}	27.12 ^b	61.12 ^b	59.12 ^b
%CV	21.03	14.99	20.32	27.96	20.72	22.36	15.01	6.06	6.32

Note: Means with different letters are significantly different at the 5% level ($p < 0.05$). For weeks where $p > 0.05$, no significant differences were observed among treatments.



Figure 4. Image of the spathe at the -3 stage, -2 stage (meiosis), and -1 stage (mitosis) of emergence.

The data revealed no significant differences in weeks 0, 4, and 6, but the treatments were significantly different in weeks 2, 8, 10, 12, 14, and 16. However, between weeks 10 and 12, flower counts decreased, as several flowers had already transitioned into immature nuts. By week 14, the emergence and opening of spathes accounted for the observed increase in female flowers. The number of female flowers in the control group (t1) increased consistently, from 32.33 at week 0 to 83.66 at week 8. At week 10, the control group recorded the highest number of female flowers at 63.88, indicating the slowest transition of flowers into immature nuts. By week 16, the control group averaged 64.50 female flowers, ranking second to the auxin treatment. This suggests a natural increase in female flowers even without the intervention of growth

hormones. On the other hand, auxin alone (t2) showed a notable increase in the number of female flowers. As early as week 2, the recorded number was 55.50, which was significantly higher than the control group's average of 35.66. Female flowers continued to rise, reaching an average of 90.50 by week 8. Between weeks 10 and 12, the auxin-alone group recorded the greatest number of female flowers transitioning into immature nuts, which explains its relatively low count of 33.12 flowers at week 12. However, as the weeks progressed, this treatment consistently produced the highest number of female flowers, averaging 71.75 at week 16. This suggests that auxin successfully and effectively promotes female flower production. According to [30], auxins play a crucial role in regulating numerous developmental processes in plants, which include the initiation of lateral roots, the development of leaves, and floral structures. Moreover, naphthalene acetic acid alone increased pistillate flowers in cucumber [31].

The observed fluctuation in female flower numbers between weeks 8 and 10 is due to the coconut's natural reproductive transitions. While flowers are highly receptive at week 8, over the subsequent two weeks, some of these flowers either initiate nut development or undergo button shedding, thereby reducing the visible count. The decline in female flower counts during the subsequent two weeks corresponds to the number of nuts recorded in the second and third months of the study. Early dropping of nuts, or premature abscission, is a standard physiological feature of coconut reproduction. Under standard field conditions, it is typical to observe loss rates of 10%-20% [32]. Thus, the fluctuations observed between weeks 8 and 10 align with the biological processes of nut initiation and button shedding, rather than random variability. Conversely, ethylene alone (t3) had the opposite result. The number of female flowers increased slightly during the initial weeks but decreased significantly by week 6, with a mean of 43.16. This count was clearly lower compared to the control group's 56.33. By week 8, this treatment had the fewest female flowers (58.16) among the groups, indicating that ethylene reduces female flower development over time. Over successive weeks, female flowers in the ethylene-alone group consistently showed the lowest counts, particularly at weeks 14 to 16, with averages of 60.12 and 58.12, respectively. Ethylene and precursors may have caused flower abscission in some fruits, such as apples, citrus, and grapevines [33]. Also, the study noted the prevalence of rhinoceros beetles and coconut earwigs, which greatly affected the flowers and nuts of dwarf coconuts. These pests were found on the coconut palms treated with ethylene alone. Although the extent of damage was not systematically quantified per treatment, the observed reproductive trends remain consistent with coconut biology, suggesting that pest pressure did not invalidate the overall findings. Future larger-scale studies should systematically monitor pest incidence, quantify damage per treatment, and clarify treatment effects to distinguish PGR responses from confounding biotic stress.



Figure 5. Image rhinoceros beetles and coconut earwigs

The combination of auxin and ethylene (t4), however, had a varied effect. Similar to the ethylene-alone treatment, ethylene in this group resulted in a lower female flower count at week 6, with a mean of 44.16, compared to the control group. By week 8, the number of female flowers was 64.00, slightly higher than the ethylene-alone group but still significantly lower than the control group. At weeks 14 and 16, the number of flowers was comparable to that in the ethylene-alone group, averaging 61.12 and 59.12, respectively. Previous studies suggest that ethylene has both positive and negative effects on auxin homeostasis. Ethylene can

interfere with auxin signaling and transport, leading to premature abscission of female flowers [34]. While these processes may provide a credible explanation for the observed results, the current study's experimental design does not permit a clear separation of dose effects from potential hormonal interactions. Because the concentrations used in the combination treatment were 50 ppm for each compound, it remains uncertain whether the reduced flowering response of the nuts reflects true antagonism or simply the lower auxin concentration compared to the 100 ppm auxin-alone treatment.

3.3 Yield and Yield Components

3.3.1 Average Number of Nuts per Tree per Month

Based on observations, some bunches were recorded at the +3 stage, characterized by fruit set, endocarp lignification, and the formation of liquid endosperm. Other bunches were classified in the stage of increasing sugar concentration in the liquid endosperm and the initial formation of solid endosperm. Additionally, some bunches were recorded at the +11 stage, indicating mature fruits that are ready for harvest. Variation in the number of nuts was observed due to the shedding of immature nuts and the transition of female flowers into immature nuts, especially in the third month. The data revealed significant differences among treatments in the first and second months, but none in the third and fourth months. Auxin and ethylene application did not result in abortion of existing nuts. Nonetheless, given the study's limited 4-month duration, it remains inconclusive whether these treatments directly contribute to the observed increase in nut number.

Table 5. Average number of nuts per tree per month of tacunan dwarf applied with plant growth regulator

Average Number of Nuts per Tree per Month				
Treatment	1 st Month	2 nd Month	3 rd Month	4 th Month
t ₁ - water only	46.33 ^b	38.17 ^b	74.75	71.12
t ₂ - auxin alone (100 ppm every two weeks)	50.33 ^{ab}	46.00 ^{ab}	97.12	94.12
t ₃ - ethylene alone (100 ppm every two weeks)	70.50 ^a	66.00 ^a	90.12	87.00
t ₄ - combination (100 ppm every two weeks)	58.67 ^{ab}	54.83 ^{ab}	84.75	80.88
%CV	18.35	19.82	23.25	22.96

Note: Means with different letters are significantly different at the 5% level ($p < 0.05$). For months where $p > 0.05$, no significant differences were observed among treatments.

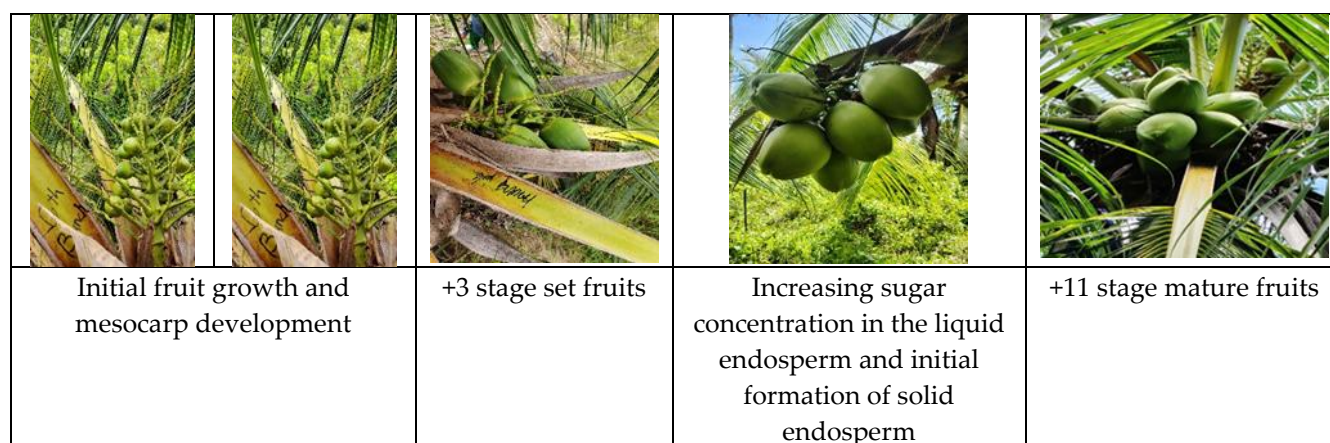


Figure 6. Development stages of the tacunan dwarf coconut.

In the first two months, ethylene alone outperformed all other treatments, yielding an average of 70.50 nuts in the first month and 66.00 in the second month. These values were notably higher than those of the control group, which recorded 46.33 nuts in the first month and declined slightly to 38.17 in the second month. This supports the findings of [11], who reported that pollination triggers genes responsible for ethylene

production, a hormone essential for the development of the ovary, ovules, and gametophytes in orchids. This genetic response is carefully regulated, occurring at specific times and in specific tissues during flower development, and forms the basis of successful fruit set. Furthermore, ethylene signaling during pollination modifies pollen tube growth by regulating cell wall remodeling and calcium gradients in tomato, thereby increasing fruit set [35]. During the third and fourth months, however, the auxin-alone treatment produced the highest absolute values, peaking at 97.12 nuts in the third month and 94.12 in the fourth month, although the differences were not statistically significant. Similar effects were reported in pepper treated with NAA, where auxin application increased fruit set [36]. Likewise, [37] found that applying 4-chlorophenoxyacetic acid, a synthetic growth regulator with auxin-like properties, enhanced fruit set in summer-grown tomato, resulting in a higher overall yield. Meanwhile, the combination of auxin and ethylene consistently produced more nuts than the control, with averages of 58.67 and 54.83 in the first and second months and 84.75 and 80.88 in the third and fourth months, respectively. These findings suggest that ethylene and auxin, whether applied individually or in combination, may play a critical role in enhancing nut development and retention, thereby increasing yield.

3.3.2 Average Nut Size (cm) and Nut Weight (g) at harvest

Nuts classified at the +11 stage, representing mature fruits, were harvested and measured for nut size and nut weight. These measurements provide descriptive baseline information on the experimental palms during the study period. Given that coconut nut development requires approximately 11–12 months from pollination to maturity, and the present study lasted only 4 months with PGR application limited to the first 2 months, the harvested nuts were already well developed before the experiment began. Therefore, these physical measurements of the nuts do not reflect the influence of PGRs.

Table 6. Average nut size at harvest and average nut weight at harvest of tacunan dwarf applied with plant growth regulators

Treatment	Average Nut Size at Harvest (cm)	Average Nut Weight at Harvest (g)
t ₁ - water only	55.42	2764.70
t ₂ - auxin alone (100 ppm every two weeks)	59.77	2896.04
t ₃ - ethylene alone (100 ppm every two weeks)	59.20	2579.05
t ₄ - combination (100 ppm every two weeks)	58.08	2721.57

These data serve as a baseline characterization of the palms under experimental conditions, providing a benchmark for future investigations. To determine whether plant growth regulators affect nut initiation, development, and yield components, longer-term studies covering a full reproductive cycle are necessary.

4. Conclusions

This study provides preliminary evidence suggesting that auxin may enhance female flower production and that ethylene may influence flowering time, nut set, and retention in coconut palms under alkaline soil and drought stress. However, given the limited sample size and high variability among experimental units, the results should be regarded as preliminary. While the treatments also revealed promising effects on nut weight and size, the dataset precludes broad generalizations as treatments were applied when the nuts were already developing. Observations from the combination treatment showed a reduced flowering response compared to auxin alone, but the experimental design does not permit clear separation of dose effects from potential hormonal interactions. Additionally, the lack of systematic documentation of pest incidence represents an additional limitation that may have contributed to variability in reproductive responses. By highlighting the potential role of plant growth regulators in reproductive development, the present study helps address a gap in coconut physiology research. These findings may serve as a baseline for future, larger-scale investigations that can more rigorously validate and confirm the observed effects under diverse field conditions.

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