



Enhanced Germination and Early Growth of Tacunan Dwarf Coconut (*Cocos nucifera* L.) through Coconut Water and Auxin Injection

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Abstract: Coconut (*Cocos nucifera* L.) propagation via seednuts is limited by slow and inconsistent germination restricts uniform seedling production in coconut. This study evaluated the effectiveness of coconut water, a natural source of phytohormones, compared with synthetic auxin (NAA) on the germination and early seedling growth of Tacunan Dwarf coconuts under nursery conditions. The experiment was arranged in a randomized complete block design with four treatments: control (no injection), 200 mL NAA + 200 mL distilled water, 200 mL coconut water + 200 mL distilled water, and a combination of NAA + coconut water (100 mL each) + 200 mL distilled water, with four replications. Treatments were applied by injecting the solution near the soft eye at 10 ml/seednut, and germination and growth parameters were recorded over 120 days. Coconut water significantly reduced the time to plumule emergence (61.00 days), produced the longest shoots (142.62 cm), shortened mean germination time (49.52 days), and increased both germination index (0.1527) and seedling vigor index (22,120.44), outperforming both NAA alone and the combined treatment, with a germination rate of 72%. In contrast, NAA resulted in the highest germination percentage (90.67%) but lower seedling vigor, while the combined treatment produced intermediate responses, suggesting no clear synergistic effect between the two stimulants. These findings demonstrate that coconut water can serve as an effective natural alternative for enhancing germination speed and early seedling growth of coconut seedlings.

Keywords: *Cocos nucifera* L., coconut water, auxin (NAA), germination, biostimulant

1. Introduction

Coconut (*Cocos nucifera* L.) is a monoecious, perennial palm belonging to the family Arecaceae. Globally, coconut is cultivated on approximately 12 million hectares of land across more than 90 countries [1], with over 80% of production concentrated in the Asia-Pacific region [2]. This makes coconut a vital source of income for many nations in the region, contributing significantly to export earnings, local economies, and cultural traditions [3]. Often referred to as the "tree of life," the coconut is valued for its versatility, as every part of the plant serves a purpose [3, 4]. It provides food, household materials, and income for an estimated 11 million smallholder farmers worldwide. Traditionally, coconut farming has focused on copra production for crude endosperm oil and dried kernel. However, recent trends show a shift toward more profitable products with nutritional and medicinal value [5], such as shell charcoal, husk fiber, virgin

coconut oil, and coconut wood used in furniture, construction, veneer, and handicrafts [6]. This wide array of products underscores coconut's importance in tropical agriculture, with an annual global output of approximately 61,165 million nuts, equivalent to 13.59 million tonnes of copra [4].

Coconut cultivation remains a cornerstone of the Philippine economy. However, Crisostomo [7] reports that the three million Filipino farmers and workers dependent on coconut face challenges such as low yields and poor productivity, largely due to the use of genetically inferior varieties. As Lee [8] points out, limited access to high-quality planting materials and low adoption of modern technologies have contributed to a decline in the total coconut-growing area. Beveridge [1] also highlights the limitations of conventional seedling production methods. Farmers must contend with climate change and extreme weather events, which further complicate cultivation [9]. Studies on seedling survival highlight that high germination capacity (the 90%) is an unreliable metric for field success compared to seed vigor [10]. Seedlings are highly vulnerable to early drought, transplant shock, or micro-climate stress within their first six months of development [11]. Domingues [12] observes that traditional seed-based propagation is hindered by slow and inconsistent germination, which delays seedling development.

In response to these challenges, this study aims to investigate the use of stimulants to enhance germination in the Tacunan Dwarf Coconut. This study seeks to understand how synthetic and organic stimulants affect the germination and early growth of coconut palms in Barili, Central Visayas, Philippines, after four (4) months.

According to Rosa [13], stimulants, whether organic or synthetic, are substances that promote germination, enhance root and shoot development, and improve seedling vigor and establishment. For example, fermented seaweed as organic stimulant could promote vegetative growth of lettuce [14] and enhanced the assimilation rate of rice bean [15]. This study will utilize two types of stimulants: coconut water as the organic treatment and auxin as the synthetic one. Auxins play a crucial role in initiating root formation, promoting shoot elongation, and suppressing lateral bud growth. Coconut water, rich in plant growth regulators, exhibits properties similar to root hormones. It naturally contains compounds such as indole acetic acid (IAA), cytokinins, abscisic acid, and salicylic acid, making it a potent supplement for plant propagation. Aishwarya [16] notes that coconut water, due to its natural auxin content, supports adventitious root formation in vegetative propagation and serves as an effective medium in micropropagation. Similarly, Setyowati [17] emphasizes that coconut water's hormonal composition can accelerate root development in plants.

2. Materials and Methods

2.1 Experimental Design and Treatments

A Randomized Complete Block Design (RCBD) was utilized to account for potential variability within the experimental area. The experiment consisted of four blocks, with each block containing all four treatments randomly assigned. Each treatment contained 10 seed nuts and was replicated four times within each block. The different treatments used in the study were as follows: T0- control (no injection), T1- Injection with 200 ml NAA + 200 ml distilled water (1:1) as stock solution, 10 ml of which is applied via syringe, T2- Injection with 200 ml coconut water + 200 ml distilled water (1:1) as stock solution, 10 ml of which is applied via syringe, T3- Injection with 100 ml coconut water + 100 ml NAA + 200 ml distilled water (1:1:2) as stock solution, 10 ml of which is applied via syringe.

2.2 Cultural Management and Practices

Proper sourcing and selection of quality seed nuts were done to ensure palm productivity. Seed nuts were sourced from the selected mother palm (Tacunan Dwarf Coconut) located in the CTU-Barili Campus. Seed nuts were disease-free, undamaged by insects and rodents, physiologically mature, without deep punctures or cuts, with water manifested by "sloshing sound" when shaken, ungerminated, and resembled the distinct appearance of the specific variety of the mother palm. Seed nuts were appropriately watered, weeded, and inspected for disease and pest incidence. Fresh coconut water from mature Tacunan Dwarf Coconut was extracted from fully developed coconut fruits by first manually removing the husk using a dehusking tool. The hard endocarp was then cracked carefully to expose the liquid endosperm. The coconut

water was immediately poured and aseptically collected into a clean, sterilized container to prevent contamination and preserve its chemical integrity prior to use with distilled water at 1:1 (v/v) coconut water solution. The auxin solution was prepared using a commercially available liquid formulation of Alpha-Naphthalene Acetic Acid (1 gm/liter Naphthalene Acetic Acid). A measured volume of 200 mL ANAA was mixed with an equal volume (200 mL) of distilled water, resulting in a 1:1 (v/v) auxin solution. The solution was thoroughly mixed to ensure uniformity and used immediately for the experiment.

2.3 Treatment Application and Seed-nut Germination

Plant growth regulators (PGRs) were administered via vertical injection near the germ pore (soft eye) [1] of each hybrid seednut at a fixed volume of 10 mL per seednut. Following the injection of these stimulants, a preventative fungicide treatment was applied directly to the wound sites to suppress fungal pathogens and ensure optimal, disease-free growth conditions. The fungicide treatment was prepared using a 0.1% v/v concentration of azoxystrobin (Amistar 25 SC), calculated in accordance with the manufacturer's specification. This standard agricultural dilution was achieved by homogenizing 0.6 mL of the commercial liquid fungicide with 599.4 mL of distilled water, 5 ml of which is applied via pressurized sprayer to the injected part. This specific concentration effectively mitigates fungal risks while eliminating the potential for phytotoxicity, thereby establishing a safe chemical baseline for sprouting. To safeguard against excessive heat and desiccation, the treated seednuts were then maintained in a shaded nursery environment, minimizing microclimatic stress and promoting uniform early seedling development.

2.4 Data Gathered

Percent Germination. The final germination percentage was evaluated four months after treatment initiation. Calculations were performed according to the method described by [18] using the following equation:

$$GP(\%) = \left(\frac{G}{S}\right) \times 100\%$$

Where:

GP is a germination percentage

G is a number of normal germinated seeds

S is a number of total seeds

Days to Plumule Emergence. The timeline for initial sprouting was determined by tracking the day of visible plumule emergence through the fibrous outer husk for each individual seed nut. This parameter was quantified by calculating the exact number of days elapsed from the date of initial treatment application to the day of first visible emergence.

Shoot Length (cm). Four months post-treatment, seedling shoot length was measured using a standardized flexible measuring tape. Measurements were taken from the visible structural base of the seedling (at the apical surface of the nut) to the tip of the longest, fully unfurled leaf blade. To ensure measurement accuracy, curved leaves were gently straightened without applying force that could stretch or damage the plant tissue.

Mean Germination Time. The velocity and uniformity of sprout emergence were quantified using the Mean Germination Time index adapted from [19], expressed through the following equation:

$$MGT = \frac{\sum(n \times d)}{N}$$

Where:

MGT is a mean germination time

n is the exact number of individual seednuts that germinated on a specific observation day

d is the specific day number from the start of the experiment when the observation was made

N is the cumulative number of seednuts that successfully germinated

Germination Index. To evaluate the combined speed and complete success rate of sprout establishment, the Germination Index was calculated following the mathematical criteria established by [20]:

$$GI = \sum \left(\frac{G_t}{Tt} \right) = \frac{G_1}{1} + \frac{G_2}{2} + \frac{G_3}{3} + \dots + \frac{G_x}{x}$$

Where:

GI is a germination index

G_t is the number of seeds germinated on a specific day t

Tt the specific day number from the start of the experiment

X is the final day of the germination monitoring period.

Seedling Vigor Index. The overall physiological quality and seedling establishment potential were evaluated four months post-planting. The calculation followed the integrated framework established by [21]:

$$SVI = \text{Germination \%} \times \text{Average Seedling Length}$$

Statistical Tool and Analysis

Analysis of variance (ANOVA) for a randomized complete block design (RCBD) was used to analyze any significant difference in all the parameters gathered. Comparisons among means were done using Least Significant Difference (LSD) to determine the specific significant differences among treatments.

3. Results and Discussion

3.1 Germination Percentage of Seed nuts at 120 days after Injection

Figure 1 showed that coconut seed responses were treatment-specific and stage-dependent, strongly reflecting underlying hormonal regulation. Injection with 200 ml NAA + 200 ml distilled water (T_1) produced the highest germination percentage at 90.67%, which was significantly superior to all other treatments. This response highlights the critical role of auxin in stimulating seed germination by enhancing reserve mobilization, cell elongation, and early embryo growth. Similar findings have been reported by Xing [22], who demonstrated that α -naphthaleneacetic acid markedly improved seed germination and early seedling establishment through improved metabolic activity and antioxidant capacity. Auxin has also been shown to interact with abscisic acid signaling to regulate dormancy release and germination, suggesting that optimal auxin levels can shift seeds toward active growth [23].

In contrast, the control exhibited the lowest germination (33.33%), indicating that the absence of growth regulators limits physiological activation necessary for uniform germination. Treatments involving 100 ml coconut water + 100 ml NAA + 200 ml distilled water (T_3) resulted in moderate germination and similar germination percentages (72%) to using only coconut water (T_2). Coconut water is known to contain natural growth-promoting substances, including cytokinins and small amounts of auxins and gibberellins, which can stimulate cell division and metabolic activity [24]. However, its comparatively lower effectiveness during germination may be attributed to variability in hormone concentration and composition, as documented by Ge [25], who reported fluctuating cytokinin levels in coconut water. This is also attributed to lower concentrations of hormones in natural organic sources like coconut water. The intermediate response observed in the combined treatment suggests possible hormonal interaction effects rather than additive benefits, consistent with reports that mixed growth regulators can alter hormonal balance and influence early developmental responses [26]. Overall, the results indicate that synthetic auxin at an optimal concentration is more effective than coconut water, at the same concentration, in enhancing germination, emphasizing the importance of treatment specificity during the early stages of seedling development.

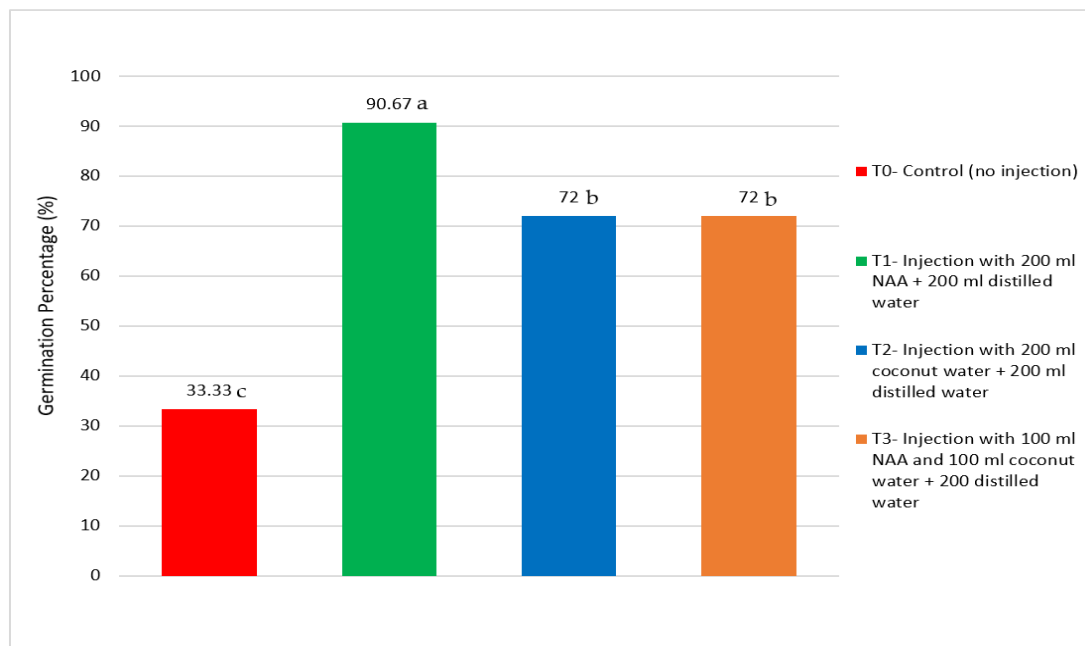


Figure 1. Germination Percentage of Seed-nuts at 120 days as Affected by Coconut Water and Auxin Injection

Table 1. Analysis of Variance (ANOVA)

Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Block	3	244.5000	81.5000	1.42	0.2985
Treatment	3	6974.6044	2324.8681	40.64	0.0000
Error	9	514.8334	57.2037		
Total	15	7733.9378			
CV (%)	11.29				
% Germination Mean	67				

Table 1.1 Least Significant Difference (LSD) Test

Alpha	0.05
Error Degrees of Freedom	9
Error Mean Square	57.2037
Critical Value	2.2622
Test Statistics	12.0982

3.2 Plumule Emergence of Seed nuts at 120 days after Injection

Figure 2 shows the emergence of shoots where that seed nuts treated with 200 ml coconut water + 200 ml distilled water (T₂) and with the combined application of 100 ml coconut water + 100 ml NAA + 200 ml distilled water (T₃) exhibited the shortest number of days to plumule emergence, indicating significantly earlier shoot development compared with the control and the NAA-only treatment (Figure 3). The rapid plumule emergence observed under coconut water-based treatments can be attributed to the presence of naturally occurring cytokinins, auxins, gibberellins, sugars, amino acids, and vitamins, which collectively stimulate cell division, enhance metabolic activity, and promote meristematic growth during early seed development [24]. Coconut water has been widely reported as an effective natural biostimulant capable of accelerating germination and shoot initiation by improving embryo physiological readiness and hormonal balance [24,27]. In contrast, the 200 ml NAA + 200 ml distilled water (T₁) did not significantly reduce the number of days to plumule emergence and performed similar to the untreated control, suggesting that a higher concentration of synthetic auxin applied alone may not favor early shoot differentiation. This response is consistent with plant physiological principles, indicating that auxins must be applied within optimal concentration ranges, as excessive auxin can suppress or delay shoot initiation by disrupting hormonal

equilibrium [28]. Furthermore, the comparable performance of coconut water alone and its combination with low-dose NAA suggests that naturally balanced hormone sources may be more effective than single synthetic regulators in controlling early growth processes, a trend also documented in plant propagation and embryo development studies [27, 29]. Overall, the figure highlights the strong potential of coconut water-based treatments in significantly shortening the time to plumule emergence, thereby improving early seed nut establishment and seedling vigor.



Figure 2. Morphological growth stages of Tacunan Dwarf Coconut (*Cocos nucifera*) seednuts (clockwise) during germination: **(a)** first sign of sprout emergence at day 8; **(b)** clear emergence of the shoot tip “button stage” at day 15; **(c)** development of a visible, upright spear at day 31; **(d)** early opening of the blade at day 56; **(e)** unfurling and elongation of the young leaves at day 78; and **(f)** distinct separation of leaf sheets with fully visible midribs at day 93.

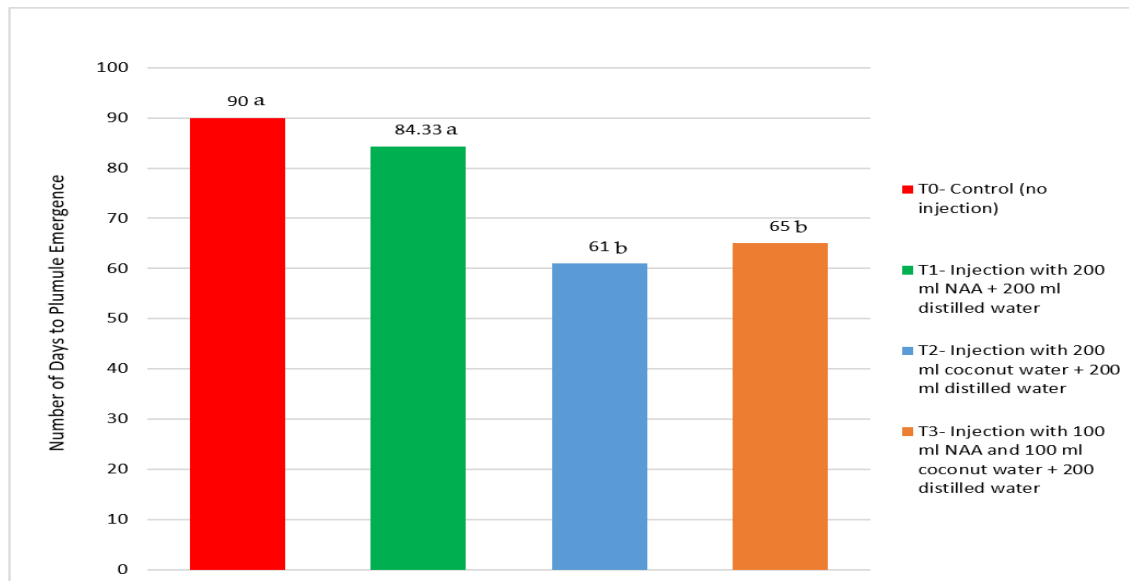


Figure 3. Plumule Emergence of Seed-nuts at 120 days as Affected by Coconut Water and Auxin Injection

Table 2. Analysis of Variance (ANOVA)

Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Block	3	21.667	7.0556	0.35	0.7877
Treatment	3	2432.2717	810.7572	40.65	0.0000
Error	9	179.5000	19.9444		
Total	15	2632.9383			
CV (%)	5.95				
Plumule Emergence Mean	75.08				

Table 2.1 Least Significant Difference (LSD) Test

Alpha	0.05
Error Degrees of Freedom	9
Error Mean Square	19.9444
Critical Value	2.2622
Test Statistics	7.1436

3.3 Shoot Length of Seed nuts 120 days after Injection

Average shoot length of seed nuts at 120 days after injection was significantly affected by the different treatments, as shown in Figure 4. Injection with 200 ml coconut water + 200 ml distilled water (T₂) produced the longest shoots (142.62 cm) and was significantly superior to all other treatments. This is approximately three times longer than without injection (40 cm), underscoring the beneficial effects of coconut water on shoot development. This pronounced elongation response can be attributed to the presence of naturally occurring growth regulators, particularly cytokinins, along with detectable levels of auxins and gibberellins, which collectively stimulate cell division and cell elongation in shoot tissues [24]. Coconut water has been widely reported to enhance vegetative growth due to its complex hormonal composition and nutrient content, providing a strong physiological basis for the observed shoot elongation [25]. The combined treatment of 100 ml NAA and 100 ml coconut water + 200 ml distilled water (T₃) resulted in intermediate shoot length (94.40 cm), which was significantly lower than coconut water alone but higher than NAA alone. This suggests that the combined application did not produce additive effects, likely due to hormonal interactions that altered the balance between auxin-mediated elongation and cytokinin-regulated cell division. Similar non-additive responses have been documented when coconut water is applied together with synthetic growth regulators, indicating that optimal shoot growth depends on precise hormonal balance rather than multiple hormone

sources [26]. Injection with 200 ml NAA + 200 ml distilled water (T_1) produced moderate shoot elongation (88.67 cm), which was significantly higher than the control. Although auxin is known to promote cell elongation, its effect is often concentration- and stage-dependent, and excessive auxin may limit sustained shoot elongation during later growth stages [23]. The control treatment (T_0) recorded the shortest shoots (40 cm), reflecting the absence of external growth stimulation. Overall, these findings indicate that coconut water is the most effective treatment for promoting shoot elongation, whereas auxin application alone primarily supports early growth stages rather than sustained vegetative expansion [30].

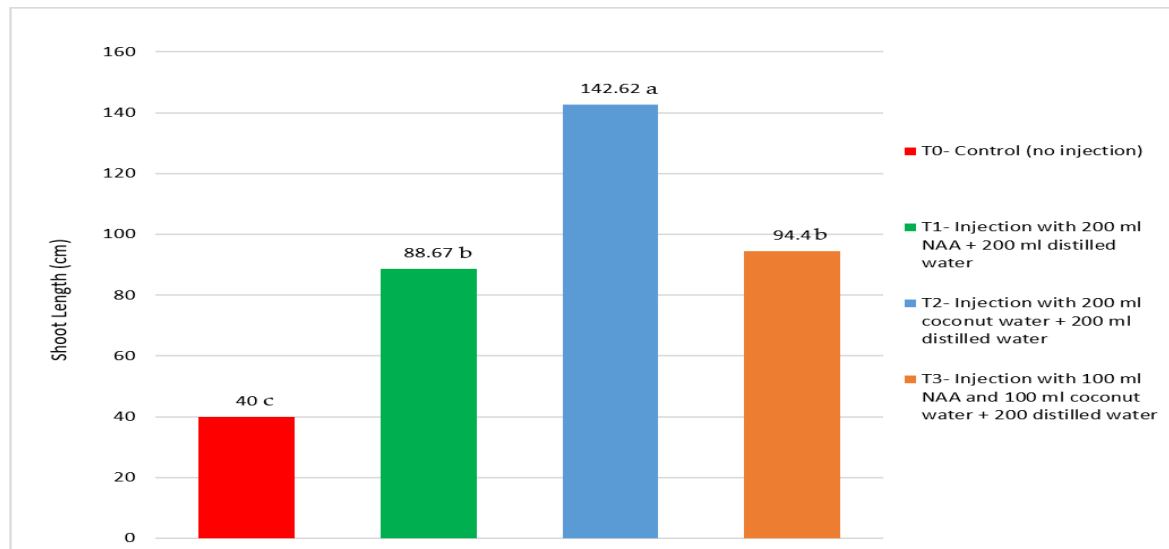


Figure 4. Shoot Length of Seed-nuts at 120 days as Affected by Coconut Water and Auxin Injection

Table 3. Analysis of Variance (ANOVA)

Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Block	3	119.7254	39.9085	0.40	0.7563
Treatment	3	21126.6282	7042.2094	70.61	0.0000
Error	9	897.5829	99.7314		
Total	15	22143.9366			
CV (%)	10.92				
Shoot Length Mean	91.42				

Table 3.1 Least Significant Difference (LSD) Test

Alpha	0.05
Error Degrees of Freedom	9
Error Mean Square	99.7314
Critical Value	2.2622
Test Statistics	15.9744

3.4 Mean Germination Time at 120 days after Injection

Figure 5 indicates that the mean germination time (MGT) of Tacunan Dwarf seednuts was significantly reduced by all injection treatments compared to the control group (T_0), which recorded the longest MGT at 103.38 days. Notably, the injection of 200 mL coconut water combined with distilled water (T_2) achieved the most rapid germination with an MGT of 49.52 days, outperforming both the 200 mL NAA treatment (T_1 ; 53.66 days) and the combined injection (T_3 ; 59.90 days). This pronounced acceleration of MGT serves as a vital indicator of increased germination speed and enhanced seed vigor [10], demonstrating that coconut water drives the physiological processes leading to radicle protrusion more effectively than synthetic hormones alone or in combination. This superior performance aligns with findings by [31], who reported that

coconut water priming reduces germination time by enhancing metabolic activity and reserve mobilization. As a natural biostimulant, coconut water contains essential endogenous growth regulators such as auxins, cytokinins, and gibberellins that work synergistically to break seed dormancy and stimulate embryo emergence by facilitating hydrolytic enzyme synthesis and cell elongation [32-35]. Concurrently, while the application of NAA (T₁) provides a synthetic auxin source that promotes cell division and elongation to accelerate germination physiology [36], its combination with coconut water (T₃) proved less effective than the pure organic treatment. This response suggests a possible hormonal antagonism or receptor saturation when synthetic and natural auxins are applied simultaneously, ultimately emphasizing that coconut water provides a highly efficient, more natural stimulus that bridges traditional agricultural practices with modern plant physiology.

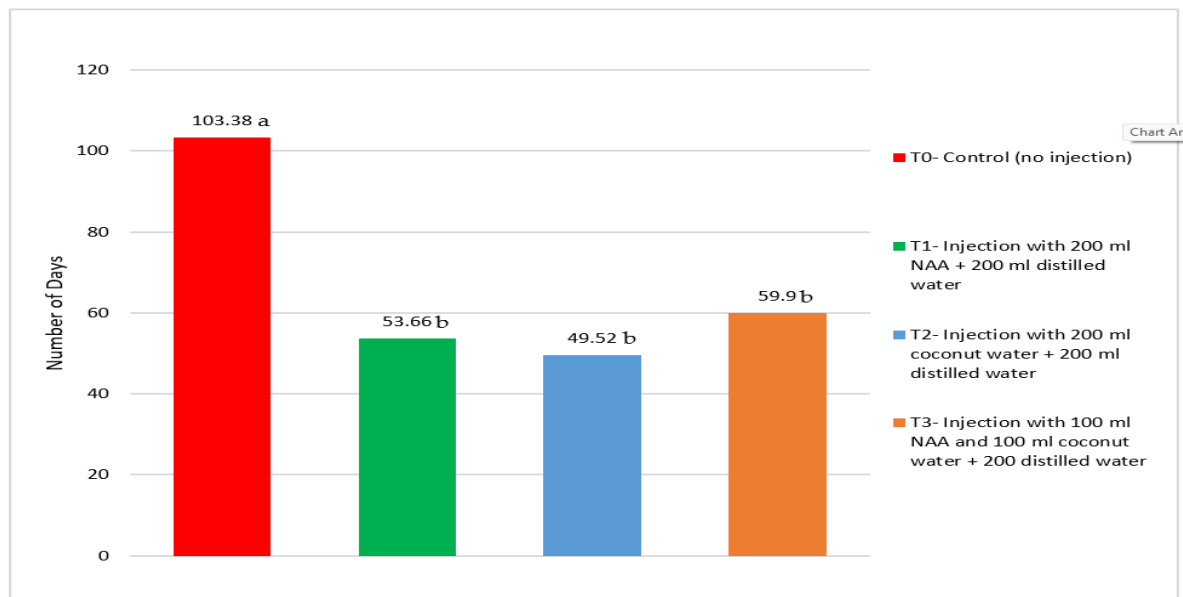


Figure 5. Mean Germination Time of Seed-nuts at 120 days as Affected by Coconut Water and Auxin Injection

Table 4. Analysis of Variance (ANOVA)

Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Block	3	438.4821	146.1607	1.59	0.2592
Treatment	3	7428.2625	2476.0875	26.91	0.0001
Error	9	827.9761	91.9973		
Total	15	8694.7207			
CV (%)	14.40				
MGT Mean	66.62				

Table 4.1 Least Significant Difference (LSD) Test

Alpha	0.05
Error Degrees of Freedom	9
Error Mean Square	91.9973
Critical Value	2.2622
Test Statistics	15.3425

3.5 Germination Index of Seed-nuts at 120 days after Injection

Figure 6 revealed that seed-nuts injected with coconut water (T₂) exhibited the highest germination index (0.1527), outperforming both NAA alone (T₁) and the combined NAA + coconut water treatment (T₃). This finding underscores the efficacy of coconut water as a natural biostimulant, likely due to its rich composition of cytokinins, gibberellins, and auxins that collectively stimulate enzymatic activity and cell division during germination. Previous studies have reported similar outcomes; [37] demonstrated that

coconut water supplementation enhanced orchid seed germination, while [33] confirmed its role in accelerating rice seed germination. These results suggest that coconut water provides a more balanced hormonal environment compared to synthetic auxin alone, thereby promoting uniform and vigorous germination. The superior performance of T₂ highlights the potential of coconut water as a sustainable alternative to synthetic stimulants in coconut propagation.

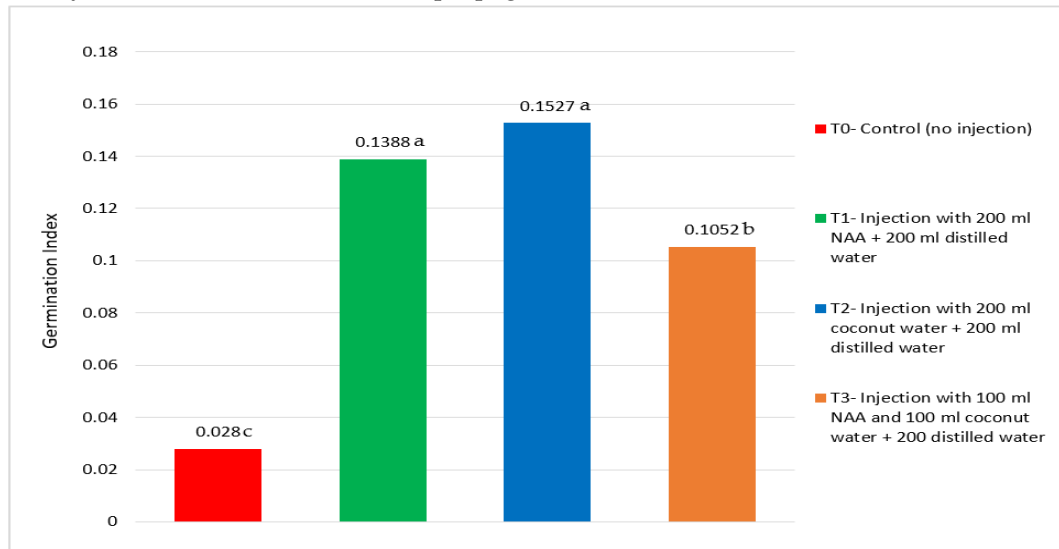


Figure 6. Germination Index of Seed-nuts at 120 days as Affected by Coconut Water and Auxin Injection

Table 5. Analysis of Variance (ANOVA)

Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Block	3	0.0017	0.0006	1.28	0.3391
Treatment	3	0.0374	0.0125	28.97	0.0001
Error	9	0.0039	0.0004		
Total	15	0.0429			
CV (%)	19.53				
Germination Index Mean	0.1062				

Table 5.1 Least Significant Difference (LSD) Test

Alpha	0.05
Error Degrees of Freedom	9
Error Mean Square	0.0004
Critical Value	2.2622
Test Statistics	0.0332

3.6 Seedling Vigor Index at 120 days after Injection

Figure 7 shows that with T₂ (Injection with 200 ml coconut water + 200 ml distilled water) achieving a value of 22,120.44 substantially higher than T₁ (Injection with 200 ml NAA + 200 ml distilled water) with 8,540.41 and the control (T₀; 1,320.8). This demonstrates that coconut water not only accelerates germination but also sustains robust seedling growth. Coconut water's diverse phytohormone profile, coupled with essential minerals and sugars, likely contributed to enhanced shoot development. [38] reported similar improvements in coconut micropropagation when auxin-rich treatments were optimized, while [31] highlighted coconut water's ability to promote balanced seedling growth in coconut seedlings. The exceptionally high vigor index in T₂ underscores coconut water's holistic role in promoting seedling establishment, making it a promising eco-friendly biostimulant for coconut cultivation.

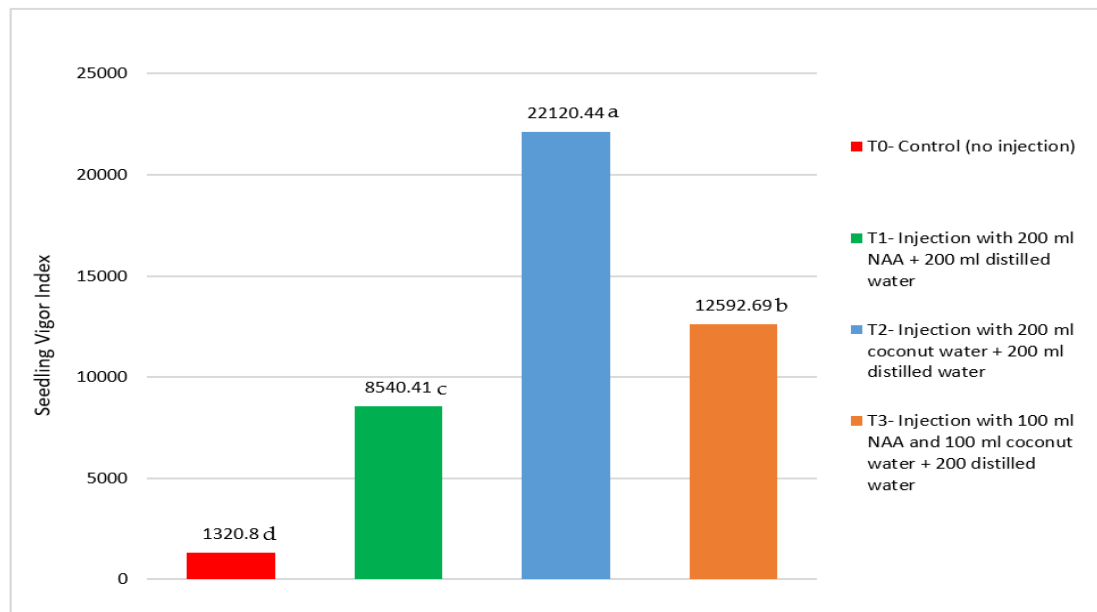


Figure 7. Seedling Vigor Index of Seed-nuts at 120 days as Affected by Coconut Water and Auxin Injection

Table 6. Analysis of Variance (ANOVA)

Source	DF	Sum of Square	Mean Square	F Value	Pr (> F)
Block	3	10835548.6229	3611849.5410	1.14	0.3851
Treatment	3	903419463.2648	301139821.0883	94.84	0.0000
Error	9	28575895.2680	3175099.4742		
Total	15	942830907.1557			
CV (%)	15.99				
SVI Mean	11143.59				

Table 6.1 Least Significant Difference (LSD) Test

Alpha	0.05
Error Degrees of Freedom	9
Error Mean Square	3175099.4742
Critical Value	2.2622
Test Statistics	2850.2729

4. Conclusions

This study demonstrated that the application of organic and synthetic plant growth stimulants significantly enhanced the germination and early seedling development of Tacunan Dwarf Coconut. Among the treatments, injection with 200 ml coconut water + 200 ml distilled water proved most effective in promoting overall seedling vigor, producing the longest shoots, achieving the earliest plumule emergence, reducing mean germination time, and increasing both germination index and seedling vigor index, highlighting its strong potential as a natural biostimulant. On the other hand, injection with 200 ml NAA + 200 ml distilled water yielded the highest germination percentage, confirming its effectiveness in stimulating embryo activation and early metabolic processes. The combined treatment (100 ml NAA + 100 ml coconut water + 200 ml distilled water) produced intermediate effects across all parameters, suggesting partial but not synergistic hormonal interactions.

Overall, the findings confirm that coconut water is a sustainable, accessible, and efficient alternative to synthetic plant growth regulators for enhancing early coconut seedling performance, especially under climate-stressed nursery conditions in Cebu, Philippines. Its use can support local coconut farmers by improving germination uniformity and accelerating early growth, thereby strengthening propagation systems for Tacunan Dwarf and other coconut varieties.

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References

- [1] Beveridge, F. C.; Kalaipandian, S.; Yang, C.; Adkins, S. W. Fruit Biology of Coconut (*Cocos nucifera* L.). *Plants* **2022**, *11*, 3293. <https://doi.org/10.3390/plants11233293>
- [2] Samosir, Y. M. S.; Rillo, E. P.; Mashud, N.; Lien, V. T. M.; Kembu, A.; Faure, M.; Adkins, S. W. Revealing the Potential of Elite Coconut Types through Tissue Culture. 2006.
- [3] Samosir, Y. M. S.; Foale, M.; Adkins, S. W. Australian Involvement in Coconut Research and Development. In *ACIAR Proceedings*; ACIAR: Canberra, 2006; Vol. 125, p 36.
- [4] Rethinam, P. Asian and Pacific Coconut Community Activities, Achievements and Future Outlook. In *ACIAR Proceedings*; ACIAR: Canberra, 2006; Vol. 125, p 15.
- [5] Foale, M. *Coconut Odyssey: The Bounteous Possibilities of the Tree of Life*; Australian Centre for International Agricultural Research: Canberra, 2003.
- [6] Nguyen, Q. T.; Bandupriya, H. D.; López Villalobos, A.; Sisunandar, S.; Foale, M.; Adkins, S. W. Tissue Culture and Associated Biotechnological Interventions for the Improvement of Coconut (*Cocos nucifera* L.): A Review. *Planta* **2015**, *242*, 1059–1076. <https://doi.org/10.1007/s00425-015-2362-9>
- [7] Crisostomo, S. D.; Cruz, C. D. D.; Quilloy, R. B.; Reaño, C. E. Narrowing the Yield Gap of Coconut (*Cocos nucifera* L.) through Integrated Nutrient Management in the Philippines: An On-Farm Experiment Approach. *IOP Conf. Ser.: Earth Environ. Sci.* **2023**, *1235*, 012008. <https://doi.org/10.1088/1755-1315/1235/1/012008>
- [8] Lee, R. Cadang Cadang Disease of Palm and Other Diseases. In *Phytopathology*; American Phytopathological Society: St. Paul, MN, USA, 2013; p 177.
- [9] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. *Supporting Smallholder Coconut Farmers in the Philippines*; 2024. <https://www.giz.de/en/worldwide/153152.html>.
- [10] Azimi, R.; Borzelabad, M. J.; Feizi, H.; Azimi, A. Interaction of SiO₂ Nanoparticles with Seed Prechilling on Germination and Early Seedling Growth of Tall Wheatgrass (*Agropyron elongatum* L.). *Pol. J. Chem. Technol.* **2014**, *16*, 25–29. <https://doi.org/10.2478/pjct-2014-0045>
- [11] Liu, D.; Yang, J.; Tao, L.; Ma, Y.; Sun, W. Seed Germination and Seedling Growth Influenced by Genetic Features and Drought Tolerance in a Critically Endangered Maple. *Plants* **2023**, *12*, 3140. <https://doi.org/10.3390/plants12173140>
- [12] Domingues Neto, F. J.; Pimentel Junior, A.; Putti, F. F.; Rodrigues, J. D.; Ono, E. O.; Tecchio, M. A.; Leonel, S.; Silva, M. S. Effect of Plant Growth Regulators on Germination and Seedling Growth of *Passiflora alata* and *Passiflora edulis*. *Horticulturae* **2024**, *10*, 1087. <https://doi.org/10.3390/horticulturae10101087>

- [13] Rosa, A. C. R.; Verly, L. B.; Miranda, G. S.; Marques, C. F. P. M.; Vieira, G. F. A.; Carvalho, G. A.; Santos, M. F. C. Natural Biostimulants for Seed Growth and Development. In *Advances in Seed Quality Evaluation and Improvement*; Springer Nature Singapore: Singapore, 2025; pp 105–126. https://doi.org/10.1007/978-981-96-5178-8_5
- [14] Pascual, P. R. L., Carabio, D. E., Rondina, M. E., Abello, N. F. H., & Pascual, V. U. (2020). Fermented seaweed (*Kappaphycus alvarezii*) by-product promotes growth and development of lettuce (*Lactuca sativa* var. Curly Green). *Plant Cell Biotechnology and Molecular Biology*, 21(71–72), 208–214.
- [15] Pascual, P. R. L., Carabio, D. E., Abello, N. F. H., Remedios, E. A., & Pascual, V. U. (2021). Enhanced assimilation rate due to seaweed biostimulant improves growth and yield of rice bean (*Vigna umbellata*). *Agronomy Research*, 19(4), 1863–1872.
- [16] Aishwarya, P. P.; Seenivasan, N.; Naik, D. S. Coconut Water as a Root Hormone: Biological and Chemical Composition and Applications. *Magnesium* **2022**, 22, 20.87, 31–65.
- [17] Setyowati, N.; Permana, I. G.; Hermansyah, H. Effect of Growing Media and Natural Plant Growth Regulators on the Growth of Tea Stem Cutting. *E3S Web Conf.* **2023**, 373, 03004. <https://doi.org/10.1051/e3sconf/202337303004>
- [18] Pangestuti, R.; Sulistyaningsih, E.; Kurniasih, B.; Murti, R. H. Improving Seed Germination and Seedling Growth of True Seed Shallot (TSS) Using Plant Growth Regulator Seed Priming. *IOP Conf. Ser.: Earth Environ. Sci.* **2021**, 883, 012024. <https://doi.org/10.1088/1755-1315/883/1/012024>
- [19] Czabator, F. J. Germination Value: An Index Combining Speed and Completeness of Pine Seed Germination. *For. Sci.* **1962**, 8, 386–396. <https://doi.org/10.1093/forestscience/8.4.386>
- [20] AOSA. *Seed Vigor Testing Handbook*; Association of Official Seed Analysts: Contribution 32, 1983; p 88.
- [21] Abdul-Baki, A. A.; Anderson, J. D. Vigor Determination in Soybean Seed by Multiple Criteria. *Crop Sci.* **1973**, 13, 630–633. <https://doi.org/10.2135/cropsci1973.0011183X001300060013x>
- [22] Xing, X.; Cao, C.; Li, S.; Wang, H.; Xu, Z.; Qi, Y.; Wang, X. α -Naphthaleneacetic Acid Positively Regulates Soybean Seed Germination and Seedling Establishment by Increasing Antioxidant Capacity, Triacylglycerol Mobilization, and Sucrose Transport under Drought Stress. *Plant Physiol. Biochem.* **2023**, 201, 107890. <https://doi.org/10.1016/j.plaphy.2023.107890>
- [23] Liu, X.; Zhang, H.; Zhao, Y.; Feng, Z.; Li, Q.; Yang, H.-Q.; Luan, S.; Li, J.; He, Z.-H. Auxin Controls Seed Dormancy through Stimulation of Abscissic Acid Signaling by Inducing ARF-Mediated ABI3 Activation in *Arabidopsis*. *Proc. Natl. Acad. Sci. U.S.A.* **2013**, 110, 15485–15490. <https://doi.org/10.1073/pnas.1304651110>
- [24] Yong, J. W. H.; Ge, L.; Ng, Y. F.; Tan, S. N. The Chemical Composition and Biological Properties of Coconut (*Cocos nucifera* L.) Water. *Molecules* **2009**, 14, 5144–5164. <https://doi.org/10.3390/molecules14125144>
- [25] Ge, L.; Yong, J. W. H.; Tan, S. N.; Yang, X. H.; Ong, E. S. Analysis of Some Cytokinins in Coconut (*Cocos nucifera* L.) Water by Micellar Electrokinetic Capillary Chromatography after Solid-Phase Extraction. *J. Chromatogr. A* **2004**, 1048, 119–126. [https://doi.org/10.1016/S0021-9673\(04\)01186-0](https://doi.org/10.1016/S0021-9673(04)01186-0)
- [26] Prando Sandoval, M. A.; Chiavazza, P.; Faggio, A.; Contessa, C. Effect of Coconut Water and Growth Regulator Supplements on *in Vitro* Propagation of *Corylus avellana* L. *Sci. Hort.* **2014**, 171, 91–94. <https://doi.org/10.1016/j.scienta.2014.03.052>
- [27] George, E. F.; Hall, M. A.; De Klerk, G.-J. *Plant Propagation by Tissue Culture*; Springer: Dordrecht, 2008. <https://doi.org/10.1007/978-1-4020-5005-3>
- [28] Taiz, L.; Zeiger, E.; Møller, I. M.; Murphy, A. *Plant Physiology and Development*, 6th ed.; Sinauer Associates: Sunderland, MA, 2015.
- [29] Arditti, J.; Ernst, R. *Micropropagation of Orchids*; John Wiley & Sons: New York, 1993.

- [30] Pascual, P. R. L. Multiple Shoot Induction of Asparagus (*Asparagus officinalis* var. UC-157) through Nodal Stem Culture Technique. *IAMURE Int. J. Ecol. Conserv.* **2013**, 6, 1. <https://doi.org/10.7718/ijec.v6i1.550>
- [31] Aguila, D. N. S. Effect of Extracted Phytohormones from Coconut Water on the Growth of Tissue-Cultured Crops and Coconut Seedlings. 2024.
- [32] Budiyo, B.; Saputra, W. T. M.; Chairani, N. Pengaruh Pemberian Zat Pengatur Tumbuh (ZPT) Air Kelapa Muda dan Lama Perendaman terhadap Viabilitas Benih Padi Varietas Lokal. *J. Agroteknol. Pertan. Publikasi Riset Ilm.* **2024**, 6, 53–58. <https://doi.org/10.55542/jappri.v6i1.1202>
- [33] Carganilla, J.; Aquino, J.; Dinay-og, J.; Cumahling, G. J.; Valdez, M. Efficacy of Coconut Water as a Seed Priming Agent for Enhancing Germination and Emergence of Rice. *J. Interdiscip. Perspect.* **2025**, 3, 199–205. <https://doi.org/10.69569/jip.2025.663>
- [34] Sudaryono, T.; Prahardini, P. E. R. Effect of Coconut Water on Seed Germination of True Seed Shallot (TSS) Trisula and Biru Lancor Varieties. *J. Pembangunan Alam Lestari* **2021**, 12. <https://doi.org/10.21776/ub.jp.al.2021.012.02.01>
- [35] Sugiono; Sudaryono, T.; Prahardini, P. E. R.; Antarlina, S. S.; Fidiyawati, E.; Ashari, H.; Latifah, E. Effect of Storage Time and Soaking of Natural Growth Regulators on True Shallot Seedling. *IOP Conf. Ser.: Earth Environ. Sci.* **2024**, 1312, 012004. <https://doi.org/10.1088/1755-1315/1312/1/012004>
- [36] Pathare, S. M.; Patil, V. S. Impact of Humic Acid and NAA on Seed Germination in Mung Bean (*Vigna radiata* L.). *Int. J. Biol. Sci.* **2025**, 7, 255–258. <https://doi.org/10.33545/26649926.2025.v7.i6d.386>
- [37] Utami, E. S. W.; Hariyanto, S. The Effect of Organic Nutrient and Growth Regulators on Seed Germination, Embryo, and Shoot Development of *Dendrobium antennatum* Lindl. Orchid by *in Vitro*. *Biosaintifika* **2016**, 8, 165–171. <https://doi.org/10.15294/biosaintifika.v8i2.5165>
- [38] Indrachapa, M. T. N.; Balasuriya, B. M. I. K.; Jayarathna, S. P. N. C.; Vidhanaarachchi, V. R. M.; Mu, Z. Optimizing Pulse Treatments for Enhanced *in Vitro* Rooting in Coconut Micropropagation. *Technol. Hortic.* **2025**, 5. <https://doi.org/10.48130/tihort-0025-0019>