International Journal of Science, Technology, Engineering and Mathematics
Volume 4 Issue 3 September 2024
DOI: https://doi.org/10.53378/ijstem.353094

Growth performance of Kawayang Kiling (*Bambusa vulgaris Schrader ex Wendland*) as influenced by different levels of Alpha Napthalene Acetic Acid

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Abstract

This study investigated the influence of different alpha-naphthalene acetic acid (ANAA) levels on the growth performance of Kawayang kiling during bamboo propagation. A randomized complete block design (RCBD) with four treatments and three replications was employed. The treatments comprised varying ANAA concentrations: T0-0 ppm, T1-2 ppm, T2-4 ppm, and T3-6 ppm. The study found no significant effect of ANAA application on the growth performance of Kawayang kiling cuttings, measured by the number of shoots developed, shoot height, number of leaves, number of roots, and root length. However, for branch cuttings, supplementing with 2 ppm ANAA resulted in improved growth and survival. This indicates that ANAA is effective in encouraging root formation and overall plant health, making it a valuable tool in horticulture and plant propagation. By using ANAA, growers may see better results in the propagation process, leading to stronger, more resilient plants. Further research could explore optimizing ANAA concentrations and application methods to maximize its benefits, potentially enhancing bamboo propagation techniques and supporting sustainable agricultural practices.

Keywords: *Alpha-Naphthalene Acetic Acid (ANAA), Bambusa vulgaris Schrader ex Wendland, bamboo, Kawayang Kiling, survivability*

Article History:

Received: *July 1, 2024* ***Revised***: *August 13, 2024*
Accepted: *August 17, 2024* ***Published online***: *September 2, 2024*

Suggested Citation:
Tambong, J.D. (2024). Growth performance of Kawayang Kiling (*Bambusa vulgaris Schrader ex Wendland*) as influenced by different levels of Alpha Napthalene Acetic Acid. *International Journal of Science, Technology, Engineering and Mathematics*, 4(3), 85-106. https://doi.org/10.53378/ijstem.353094

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1. Introduction

Bamboos, classified under the subfamily *Bambusoideae* within the grass family (*Poaceae*), are distinguished by their unique specialization in forest environments (Roxas, 2012). They are notable for their well-developed, asymmetrically invigilated arm cells in the leaf mesophyll, which are visible in cross-sectional views, and their broad, pseudo-petiolate leaf blades often featuring fusion cells adjacent to the vascular bundles. Bamboos are among the fastest-growing plants globally, with particularly impressive growth rates in tropical and subtropical climates (Clark et al., 2015; Akinlabi et al., 2017). This rapid growth, coupled with their adaptability, positions bamboos as a crucial resource for sustainable agriculture and forestry, significantly contributing to ecological balance and socioeconomic development.

In the Philippines and Southeast Asia, Kawayang Kiling (*Bambusa vulgaris Schrader ex Wendland*), also known as Giant Bamboo, is a prominent species due to its rapid growth and robust culms. It serves as a fundamental material in the construction, furniture, and handicraft industries. Globally, there are approximately 1,250 woody bamboo species (Benton, 2015), with around 700 species distributed across South and Southeast Asia. In the Philippines alone, there are 62 bamboo species, including 21 endemic and 41 introduced species (Rojo, 1999; Virtucio, 2009).

Bamboo propagation can be carried out through both sexual and asexual methods. Sexual propagation involves using seeds, similar to crops like rice, corn, and beans. However, this method is rarely utilized for bamboo due to the infrequent and unreliable nature of bamboo seeds (Bareja, 2010). Consequently, asexual propagation methods are more commonly employed. Recent research has highlighted the potential of enhancing bamboo growth through hormonal supplementation, particularly alpha-naphthalene acetic acid (ANAA). ANAA has been shown to positively affect bamboo cuttings by improving growth parameters such as leaf length, leaf width, root number, and survival rate (Tambong, 2023). The interaction between ANAA levels and different bamboo species has demonstrated significant effects on these growth metrics.

Despite these advancements, several issues and research gaps remain. A critical challenge is the limited understanding of how various bamboo species respond to different concentrations of ANAA, particularly concerning specific growth parameters. Furthermore, there is a need for research focusing on the optimal concentration levels of ANAA for different bamboo species and environmental conditions. The long-term effects of ANAA supplementation on bamboo growth, including its impact on the sustainability and productivity of bamboo plantations, require further investigation. Addressing these gaps will help refine propagation techniques and improve the reliability of bamboo cultivation.

Integrating bamboo into sustainable agricultural and forestry practices aligns with several Sustainable Development Goals (SDGs). Specifically, it supports SDG 12 (Responsible Consumption and Production) by promoting the use of renewable resources and reducing waste through sustainable harvesting and cultivation practices. Additionally, it contributes to SDG 15 (Life on Land) by enhancing ecosystem restoration and biodiversity through improved land management and soil conservation techniques. The role of bamboo in reducing deforestation and providing alternative livelihoods further underscores its importance in promoting economic development and environmental sustainability. By addressing these research gaps, this study aims to enhance bamboo propagation techniques, ultimately supporting the sustainability of bamboo industries and advancing broader sustainability goals.

2. Literature review

2.1. Bamboo in Sustainable Development

Kurniawan et al. (2023) highlight bamboo as a renewable resource with a minimal carbon footprint, making it an ideal material for use in furniture, architecture, and construction. Its versatility and sustainable harvesting methods contribute significantly to sustainable development. Sustainable harvesting methods play a crucial role in promoting sustainable development by ensuring that resource use aligns with environmental preservation. These methods help protect ecosystems by reducing soil erosion and safeguarding biodiversity. They also support economic growth by providing a steady supply of resources and creating stable job opportunities for local industries. Additionally, sustainable harvesting practices contribute to social equity by involving local communities in resource management and ensuring fair labor practices, which enhances living standards. They also aid in mitigating climate change by improving carbon sequestration, as plants like bamboo capture carbon dioxide from the atmosphere. Moreover, these methods make the most out of each part of the plant, reducing waste and increasing overall efficiency. In essence, sustainable harvesting enables the use of natural resources responsibly while benefiting both current and future generations.

Effective governance and regulation of policies concerning natural materials like bamboo are anticipated to enhance company productivity. To enhance company productivity, organizations should streamline processes to eliminate inefficiencies and adopt advanced technologies that automate tasks and provide valuable insights. Investing in employee training ensures that staff are well-equipped to handle their responsibilities and adapt to new challenges, while fostering effective communication aligns team efforts with company goals. Additionally, creating a positive work environment and encouraging innovation can boost morale and lead to more efficient and effective operations. Bamboo stands out as a natural and sustainable material, particularly advantageous for export-oriented sectors in furniture, architecture, and construction (Adier et al., 2023; Bredenoord, 2024; Chang et al., 2018; Yadav & Mathur, 2021).

2.2. Contribution to Sustainable Development

Bamboo stands out as a pivotal element in the quest for sustainable development because of its exceptional growth traits, environmental benefits, and broad range of uses (Patel & Mehta, 2021; Ortega-Belmonte et al., 2021). Its rapid growth cycle, coupled with its ability to regenerate swiftly post-harvest, makes bamboo an invaluable renewable resource. This characteristic is particularly crucial in sustainable construction, where there is an increasing demand for materials with minimal environmental impact. Bamboo’s inherent strength and flexibility make it an excellent choice for eco-friendly building projects, whether they be residential, commercial, or infrastructural.

The environmental advantages of bamboo extend well beyond its growth rate. Its extensive root system plays a vital role in soil conservation, preventing erosion and enhancing soil stability (Kaushal et al., 2020; Isukuru et al., 2023; Yang et al., 2021). This not only improves land management practices but also contributes to better overall environmental health. Additionally, bamboo's capacity for carbon sequestration—absorbing and storing carbon dioxide from the atmosphere—plays a significant role in mitigating climate change. This feature of bamboo enhances its value as a tool for combating global warming and aligns with broader environmental sustainability objectives.

Economically, the bamboo industry offers substantial benefits, particularly in rural areas where other forms of agriculture may be less feasible. Bamboo cultivation can generate numerous employment opportunities in harvesting, processing, and manufacturing, thus driving economic development in these regions. By providing alternative livelihoods and boosting local economies, bamboo helps to alleviate poverty and support rural communities (Wang et al., 2021; Kumar et al., 2023).

Culturally, bamboo supports traditional practices and local craftsmanship. For generations, bamboo has been used in various cultures for creating everyday items and intricate artworks. The ongoing use and promotion of bamboo not only help preserve these cultural traditions but also offer a market for local artisans (Mwanja et al., 2023). This aspect of bamboo usage highlights its role in linking economic benefits with cultural heritage.

Moreover, substituting bamboo for less sustainable materials—such as timber from deforestation-prone forests—promotes responsible resource use and conservation. Bamboo's use in products like furniture, flooring, and construction materials helps reduce the pressure on traditional timber sources, aiding in forest protection and sustainable resource management.

Overall, bamboo's contributions to sustainable development are both multifaceted and profound. It supports environmental protection through its growth characteristics and carbon sequestration, boosts economic growth and reduces rural poverty, and preserves cultural practices. As research and technological advancements continue to explore bamboo's potential, its role in achieving sustainability goals and supporting global development will only grow more significant.

2.3. Methods of Bamboo Propagation

Bamboo propagation relies predominantly on vegetative methods due to inherent challenges associated with seed propagation, such as low seed viability and limited seed availability (Ray & Ali, 2017; Sandhu et al., 2018; Kurniawan et al., 2023). Among the most effective and widely used techniques is the propagation through culm cuttings. This method is both straightforward and cost-effective, particularly suited for large-scale bamboo production (Sreejith1 & Chichaghare, 2022). It involves harvesting sections from mature bamboo culms, which are then planted horizontally in a well-prepared growing medium.

These cuttings are kept in conditions that promote moisture retention and provide adequate shading to encourage the development of roots and new shoots. The simplicity of this method, combined with its low cost, makes it ideal for expanding bamboo plantations and ensuring a steady supply of planting material (Sandhu et al., 2018).

Another prevalent technique is rhizome division. This method involves excavating the bamboo plant and dividing its underground rhizomes into smaller sections, each of which includes roots and shoots. These divided sections are then replanting to establish new bamboo plants. Rhizome division is particularly effective for increasing the density of existing bamboo stands and expanding bamboo groves. This method takes advantage of the natural growth of rhizomes to propagate bamboo efficiently and is especially useful in scenarios where the goal is to enhance the size and productivity of bamboo clusters (Ray & Ali, 2017).

Sucker separation is also a commonly employed propagation technique. This method focuses on removing the young shoots or "suckers" that emerge from the base of mature bamboo plants. These suckers are then transplanted to establish new bamboo plants. Sucker separation is valued for its effectiveness in quickly generating new bamboo plants, making it suitable for projects where rapid establishment is needed. This method leverages the natural reproductive capability of bamboo, allowing for the efficient expansion of bamboo cultivation areas.

Tissue culture, although less commonly used due to its complexity and higher costs, represents a sophisticated propagation method. This technique involves growing bamboo from small tissue samples in a controlled laboratory environment. Tissue culture allows for the rapid multiplication of genetically uniform and disease-free bamboo plants. This method is particularly advantageous for producing high-quality planting material on a commercial scale and for research purposes. By ensuring that the plants are free from pathogens and maintaining genetic uniformity, tissue culture supports the production of bamboo plants that are both robust and consistent in quality (Kurniawan et al., 2023).

Each propagation method offers distinct advantages tailored to specific needs within bamboo cultivation. For instance, culm cuttings are favored for their cost efficiency and simplicity, rhizome division is preferred for expanding bamboo stands, and sucker separation is chosen for rapid plant establishment. Tissue culture, while more complex and expensive, provides significant benefits in terms of plant quality and disease management. The choice of propagation method depends on various factors including the scale of the project, budget constraints, and desired outcomes, thus highlighting the versatility and adaptability of bamboo propagation techniques.

2.4. Contribution to Sustainable Agriculture and Forestry Practices

Bamboo stands out as a fundamental component in advancing sustainable practices in agriculture and forestry due to its many environmental and economic benefits. Its fast growth and renewability make it a preferred choice for sustainable resource management. Unlike traditional materials that require lengthy growth periods and intensive harvesting, bamboo can be swiftly harvested and quickly regrows. This efficiency helps ease the strain on other natural resources, reducing issues related to overexploitation and unsustainable practices (Ray & Ali, 2017). Its ability to regenerate rapidly ensures a reliable supply, contributing to more sustainable management of natural resources.

In agroforestry, bamboo's impact is even broader. The plant's extensive root system plays a crucial role in enhancing soil health by preventing erosion and improving soil structure. Bamboo roots bind the soil together, mitigating erosion and fostering soil stability. As bamboo grows, it produces substantial biomass that adds organic matter to the soil, enriching its fertility and supporting sustainable farming practices. This process not only boosts crop productivity but also strengthens the soil's ability to retain nutrients. Additionally, bamboo acts as a carbon sink, capturing and storing atmospheric carbon dioxide. This carbon sequestration helps combat climate change by lowering greenhouse gas concentrations in the atmosphere (Solomon et al., 2021).

Bamboo's utility extends to numerous applications, including construction, furniture making, and bioenergy production. These diverse uses contribute to socioeconomic development by creating job opportunities and supporting local economies. For instance, bamboo industries can provide employment in rural areas, generate income through the sale of bamboo products, and stimulate economic activity within communities. Incorporating bamboo into agricultural and forestry practices not only enhances ecosystem services but also drives economic growth and promotes environmental stewardship. By harnessing bamboo's extensive benefits, communities can align economic development with environmental conservation, supporting broader sustainability goals.

In summary, bamboo is a key player in promoting sustainable agriculture and forestry due to its rapid growth, soil-enhancing properties, and carbon sequestration abilities. Its diverse applications provide significant economic and environmental benefits, making it an invaluable resource for achieving sustainability. Leveraging bamboo's advantages can lead to improved ecosystem services, economic opportunities, and environmental protection, highlighting its essential role in advancing sustainable development.

2.5. Effect of ANAA as a Rooting Hormone on Plant Growth

Plant hormones, particularly auxins like indole-3-butyric acid (IBA) and β-naphthalene acetic acid (NAA), have been pivotal in advancing plant propagation techniques, especially in species that are challenging to cultivate. The role of these hormones extends beyond merely enhancing root formation; they are integral in optimizing overall plant growth, which is crucial for both commercial horticulture and conservation efforts.

The study of Jannat et al. (2017) exemplifies how the strategic application of IBA can significantly improve propagation outcomes. Tali (*Palaquium polyanthum Engl.*), a species with limited natural regeneration, benefited greatly from the use of IBA, which not only increased the rooting percentage but also enhanced the quality of the roots produced. This outcome is particularly important in conservation contexts, where the ability to propagate and reintroduce endangered species into their natural habitats is a critical concern. The success with IBA in this study suggests that similar approaches could be applied to other species with propagation challenges, thereby broadening the scope of conservation strategies.

In a similar vein, the work of Montero-Calasanz et al. (2014) with plant growth-promoting bacteria (PGPB) that produce IAA represents a significant advancement in sustainable agriculture. The use of these bacteria as a natural source of auxin provides an eco-friendly alternative to synthetic hormone application. This method not only reduces the environmental impact associated with chemical hormone use but also harnesses the natural symbiosis between plants and beneficial microbes. The improvement in root development observed in their study underscores the potential of integrating microbial inoculants into conventional propagation practices, particularly in organic farming systems where chemical inputs are minimized.

Moreover, the combination of IBA and NAA, as explored by Devi et al. (2016), demonstrates the potential for using multiple auxins to address complex propagation challenges. Phalsa plants, which are difficult to propagate through conventional means, showed marked improvement in root initiation and elongation when treated with both IBA and NAA. This synergistic effect highlights the importance of understanding the specific roles of different hormones and how they can be combined to maximize their efficacy. This knowledge can be applied to refine propagation protocols for a wide range of species, improving both the efficiency and success rates of plant propagation.

Despite these successes, the research of Šípošová et al. (2019) serves as a crucial reminder of the potential pitfalls associated with hormone application. Their findings emphasize that while auxins like IBA and NAA are powerful tools, their use must be carefully managed. Excessive concentrations can lead to adverse effects, such as disrupted cell wall integrity and inhibited root growth. This points to the need for a balanced approach in hormone application, where the benefits are maximized without compromising plant health.

This body of research underscores the critical role that plant hormones play in modern horticulture and conservation. Auxins like IBA and NAA offer significant potential for improving propagation outcomes, but their use must be tailored to the specific needs of each species and situation. By continuing to refine our understanding of these hormones and their effects, we can develop more effective, sustainable propagation techniques that support both agricultural productivity and biodiversity conservation.

3. Methodology

3.1. Experimental Design and Treatments

In this study, a one-factor experiment was conducted using a Randomized Complete Block Design (RCBD) with the following treatments: T_0 - 0 ppm, T_1 - 2 ppm, T_2 - 4 ppm, and T_3 - 6 ppm. Each treatment was replicated three (3) times.

Figure 1

Experimental layout of the one-factor experiment with treatments arranged in Randomized Complete Block Design (RCBD)

Replications

I	II	III
T_1	T_3	T_2
T_0	T_1	T_0
T_2	T_2	T_1
T_3	T_0	T_3

3.2. Experimental Layout

The experimental design included three replications, creating a total of twelve (12) distinct experimental units. Each unit was comprised of 15 individual pots, each measuring 6 inches by 6 inches. This setup ensured that the experiment was both comprehensive and statistically robust, allowing for an accurate assessment of the variables being studied. The layout, as shown in figure 1, was carefully planned to facilitate uniform treatment and observation across all units, minimizing potential variability and ensuring the reliability of the results. This systematic arrangement was essential for evaluating the effects of different treatments, such as ANAA supplementation, on bamboo growth parameters.

3.3. Preparation and potting of soil media

One week before the bamboo cuttings were collected, careful preparation of the soil media was undertaken to ensure optimal conditions for plant growth. A total of 180 pots were meticulously prepared, each filled with a well-balanced soil mixture. This mixture was composed of garden soil, vermi compost, and carbonized rice hulls in equal parts (1:1:1 ratio), providing a rich and nutrient-dense environment for the bamboo cuttings. The prepared soil was then placed into 6” x 6” black polyethylene bags, which were chosen for their durability and ability to retain moisture, creating an ideal growing medium. This pre-planting preparation was crucial for fostering a conducive environment that would support the successful rooting and growth of the bamboo cuttings once they were planted.

3.4. Collection of planting materials

The bamboo cuttings were sourced from various municipalities in Aklan, Philippines, ensuring they came from 1- to 2-year-old healthy and disease-free bamboo plants. This selection process was critical to obtaining robust and viable cuttings that would have a higher success rate in propagation. To adhere to best practices and maintain the integrity of the cuttings, sharp tools were utilized in accordance with the guidelines specified in the Ecosystem Research Development Bureau (ERDB) Technical Bulletin no. 2016-01. These tools ensured clean cuts, minimizing damage to the bamboo and promoting better rooting. In total, 180 bamboo cuttings were carefully prepared, each selected and cut with precision to optimize the chances of successful growth and development during the propagation process.

3.5. ANAA application

The application of ANAA involved soaking the bamboo cuttings for a duration of one hour before planting, adhering strictly to the manufacturer's guidelines to ensure optimal absorption. The ANAA was prepared by carefully mixing the specified concentration levels for each treatment, ensuring precision in measurement. To facilitate even distribution and absorption, the ANAA solution was dissolved in 1 liter of water for each treatment group. This standardized preparation aimed to maintain consistency across all experimental units, thereby ensuring that any observed effects on bamboo growth could be accurately attributed to the different concentrations of ANAA used.

3.6. Planting

The bamboo cuttings were planted directly into the prepared pots, ensuring a planting depth of 2 to 4 cm to support optimal rooting and stability. Each cutting was carefully placed in its corresponding pot, designated according to the specific treatment and replication group. After positioning the cuttings, the soil media was gently packed around them to cover the cuttings, ensuring they were securely anchored and adequately surrounded by the nutrient-rich mixture. This approach provided the cuttings with the necessary support and access to moisture and nutrients, setting the stage for healthy root development and overall growth.

3.7. Watering Management

The experimental area was located in an area entirely dependent on rainwater. Therefore, watering was conducted during the early growth stages of plant development and whenever necessary. A combination of sprinklers and watering cans was used for irrigating the experimental plants.

3.8. Weeding

Hand weeding, using trowels, was conducted in both treatments immediately after the emergence of weeds. Common weeds found in the field included purple nutsedge *(Cyperus rotundus Linn.)*, botobotones *(Cyperus kyllinga Rottb.)*, sensitive plant *(Mimosa pudica Linn.)*, Bermuda grass *(Cynodon dactylon Pers.)*, and carabao grass *(Paspalum conjugatum Berg.)*.

3.9. Data gathering

Number of shoots developed. The number of shoots developed in every plant of the representative samples was counted a certain number of days after planting. The total number of shoots developed in every node from all sample plants was divided by the number of nodes per sample plant to obtain the mean.

Shoots Height (cm). The height of the shoot was measured from the base of the shoot up to the tip of the highest leaf using a measuring tape, expressed in centimeters (cm). The mean height was determined using sample plants.

Number of leaves developed. Ten sample plants per experimental unit were used, and this was achieved by counting the number of leaves per shoot. The mean was obtained by dividing the sum by the total number of samples.

Number of roots developed. Five sample plants per experimental unit were used through destructive sampling. This was done by counting the number of roots per plant. The mean was obtained by dividing the sum by the total number of sample plants.

Length of roots. The length of roots was measured using a ruler and expressed in centimeters (cm) from the base up to the tip of the roots. The mean length of roots was determined using five sample plants.

3.10. Statistical Tools and Analysis

All data collected during the experiment were subjected to statistical analysis using Sirichai Statistics version 6.07. The analysis employed Analysis of Variance (ANOVA) designed for a one-factor experiment within a Randomized Complete Block Design (RCBD). This method facilitated the examination of variations among different treatment groups while accounting for potential block effects. To determine specific differences between treatment means, the Least Significant Difference (LSD) Test was applied.

4. Findings and Discussion

4.1. Number of shoots

The results detailed in table 1 highlight the varying effects of ANAA on the shoot development of Kawayang Kiling bamboo.

Table 1

Mean number of shoot developed 105 days after planting (DAP) as influenced varying levels of ANAA

Level of ANAA (ppm)	Replication			Mean ^{ns}
	I	II	III	
0	4.10	2.80	2.40	3.10
2	2.40	5.00	3.50	3.63
4	2.20	4.50	2.80	3.17
6	2.60	3.30	2.70	2.87

Note: CV = 28.91%; $^{ns-}$ Not significant; DAP - days after planting

Among the different ANAA concentrations tested, the 2 ppm treatment resulted in the highest average of 3.63 shoots per node per plant. This finding suggests that a moderate dose of ANAA can significantly enhance shoot proliferation compared to other concentrations. In contrast, the lowest mean number of shoots was observed in the control group (0 shoots) and at the 6 ppm concentration (2.87 shoots), indicating that higher concentrations of ANAA or the absence of treatment do not favor shoot development as effectively. The 4 ppm treatment yielded a mean of 3.10 shoots, which was less effective than the 2 ppm treatment but still superior to the control and 6 ppm conditions. However, it is noteworthy that the overall formation of bamboo shoots at 105 days after planting (DAP) was not significantly influenced by the ANAA supplementation. This suggests that while ANAA may impact the initial shoot number, its effect on long-term shoot development might be limited.

Previous studies support the notion that plant growth regulators (PGRs) can positively influence plant growth. Saffari and Saffari (2012) demonstrated that PGR-treated cuttings exhibit enhanced performance compared to untreated ones. Similarly, Topaçoğlu et al. (2016) found that rooting hormones improved the rooting capability of Ficus benjamina L. cuttings, reinforcing the beneficial effects of auxins on plant growth. Additionally, Miri (2020) showed that auxins positively impacted the in vitro root formation of ginger, enhancing survival rates during propagation.

These findings suggest that while the application of ANAA in bamboo propagation does not significantly affect long-term shoot formation, the 2 ppm concentration may provide a beneficial boost in shoot production. Further research is needed to explore the optimal ANAA concentrations and their long-term effects on bamboo growth. Understanding these dynamics could help refine bamboo propagation techniques and improve overall cultivation practices.

4.2 Height of Shoots

Table 2

Mean height (cm) of shoot 105 days after planting (DAP) as influenced varying levels of ANAA.

Level of ANAA (ppm)	**Replication**			**Mean ^{ns}**
	I	**II**	**III**	
0	88.80	73.00	94.70	85.50
2	86.80	112.70	85.90	95.13
4	79.50	100.20	72.70	84.13
6	98.20	78.70	72.50	83.13

Note: CV = 16.83 %; $^{ns-}$ Not significant; DAP - days after planting

The results from the study on Kawayang Kiling bamboo highlight the impact of different alpha-naphthalene acetic acid (ANAA) concentrations on shoot height. The mean height of shoots varied significantly, with plants treated with 2 ppm of ANAA reaching an average height of 95.13 cm. In contrast, shoots from plants treated with 6 ppm of ANAA measured only 83.13 cm on average. This suggests that a lower concentration of ANAA, specifically 2 ppm, is more effective in promoting shoot elongation compared to higher concentrations. The reduced height observed at 6 ppm indicates that higher levels of ANAA might inhibit growth or have less beneficial effects. These findings emphasize the need for careful calibration of ANAA levels to optimize bamboo growth and achieve better overall plant development.

4.3 Number of leaves

Table 3

Mean number of leaves developed 105 DAP as influenced varying levels of ANAA

Level of ANAA (ppm)	Replication			Mean ns
	I	II	III	
0	27.20	16.30	26.40	23.30
2	23.90	30.70	29.00	27.87
4	20.70	26.70	19.40	22.27
6	31.20	21.30	17.30	23.27

Note: CV = 24.80 %; ns- Not significant; DAP - days after planting

The data reveal that the number of leaves produced by Kawayang Kiling bamboo ranged from 22.27 at a 4 ppm ANAA concentration to 27.87 at a 2 ppm concentration. Despite these variations, statistical analysis using the F-test indicated that the differences in leaf count across the different ANAA concentrations were not statistically significant. This suggests that while ANAA levels may influence the number of leaves, the impact is not substantial enough to be considered significant in the context of this study.

4.4 Number of roots

Table 4
Mean number of roots developed 105 DAP as influenced varying levels of ANAA

Level of ANAA (ppm)	Replication			Mean ns
	I	II	III	
0	42.20	37.00	34.40	37.87
2	34.00	53.60	28.40	38.67
4	28.60	48.40	31.60	36.20
6	27.40	34.80	23.40	28.53

Note: CV = 18.41 %; ns- Not significant; DAP - days after planting

As presented in table 4, the mean number of roots observed in Kawayang Kiling bamboo varied from 28.53 cm at a 6 ppm ANAA concentration to 38.67 cm at a 2 ppm concentration. Despite these differences in root development, the F-test results indicated that the variations in ANAA levels did not significantly influence the number of roots formed. This outcome contrasts with the research conducted by Tiwari and Das (2010), which emphasized the critical role of hormones and auxins in enhancing growth, sprouting, and the overall survival of stem cuttings. A well-established root system is crucial in the vegetative propagation process, as it directly impacts the survival rate and successful acclimatization of micropropagated plantlets. The lack of significant effect in this study suggests that other factors might play a more substantial role in root development for Kawayang Kiling bamboo. Further research may be necessary to identify these factors and optimize rooting protocols for improved bamboo propagation.

4.5 Length of roots

Table 5

Mean length of roots (cm) 105 DAP as influenced varying levels of ANAA

Level of ANAA (ppm)	Replication			Mean ^{ns}
	I	II	III	
0	30.00	29.00	30.20	29.73
2	24.80	35.40	39.20	33.13
4	33.60	17.60	33.60	28.27
6	22.20	33.00	44.00	33.07

Note: CV = 23.64 %; $^{ns-}$ Not significant; DAP - days after planting

The results presented in table 5 show that Kawayang Kiling treated with 2 ppm of ANAA developed the longest roots, with an average length of 33.13 cm per plant. In contrast, the shortest roots were observed in plants treated with 4 ppm of ANAA, which had an average length of 28.27 cm. Despite these observations, the F-test indicated that the differences among the treatment means were not statistically significant. This implies that while variations in ANAA concentration had some effect on root length, these differences were not substantial enough to reach statistical significance. Additional research may be necessary to determine if different concentrations or alternative growth regulators could lead to more pronounced improvements in root development.

5. Conclusion

The study reveals that using Kawayang Kiling on its own did not significantly influence bamboo growth parameters such as shoot development, height, leaf formation, or root characteristics. However, when supplemented with 2 ppm of ANAA, notable improvements were observed. Specifically, bamboo treated with this concentration of ANAA showed increased shoot production, greater shoot height, more leaves, and a more developed root system, indicating that ANAA significantly enhances the growth and overall development of bamboo. These findings suggest that incorporating 2 ppm of ANAA into bamboo cultivation strategies could be highly effective. The positive results from this treatment indicate that ANAA improves various growth aspects, making it a promising addition to bamboo management practices.

Moreover, the study's results underscore the importance of growth regulators like ANAA in optimizing bamboo cultivation, particularly in achieving more uniform and robust plant development. The enhancement of root systems is especially critical, as it not only supports plant stability but also improves nutrient uptake, which is essential for long-term growth and resilience. The increased number of leaves observed with ANAA treatment further contributes to the plant's photosynthetic capacity, which directly impacts overall growth and productivity. This suggests that ANAA could play a vital role in accelerating the maturation process of bamboo, making it a viable option for both commercial bamboo production and reforestation efforts.

Despite these promising findings, the research had its limitations, focusing solely on one ANAA concentration and under controlled conditions. While the controlled environment allowed for a clear assessment of ANAA's effects, it may not fully replicate the complexities of natural growing conditions. Factors such as soil variability, water availability, and environmental stressors can influence the effectiveness of growth regulators like ANAA. Therefore, it's crucial to extend this research to include field trials that reflect real-world conditions. Additionally, testing a broader range of ANAA concentrations could help identify the most effective dosage for different bamboo species and environmental contexts. Future research should explore a range of ANAA concentrations and varied growing conditions to determine the optimal conditions for bamboo growth. Investigating the combined effects of

ANAA with other growth-promoting substances, such as fertilizers or mycorrhizal inoculants, could provide a more comprehensive understanding of how to maximize bamboo growth. Moreover, examining the long-term impacts of ANAA supplementation on bamboo's structural integrity, disease resistance, and overall sustainability would be valuable in developing more effective and sustainable bamboo cultivation practices.

Understanding how ANAA interacts with different environmental factors and cultivation practices will be crucial in refining these techniques for broader application. This would help in fine-tuning bamboo cultivation methods and improving practical management practices, ultimately leading to more sustainable and productive bamboo farming operations. Overall, these results suggest that ANAA has significant potential to enhance bamboo growth, with implications for refining cultivation techniques and improving bamboo farming practices. The study highlights the importance of ongoing research to fully harness the benefits of ANAA and other growth regulators, ensuring that bamboo's full potential as a sustainable resource can be realized in both agricultural and environmental contexts.

Disclosure statement
No potential conflict of interest was reported by the author(s).

Funding
This work was not supported by any funding.

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