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Effects of Coconut Water and Bean Sprout Extract as Natural Plant Growth Regulators on the Vegetative Growth of Mulberry Cuttings (*Morus alba* L.)

Dwi Nurmawanti [1]*, Edy[1] and Anwar[1]

[1] Agrotechnology Study Program, Faculty of Agriculture and Mine Land Bioremediation, Universitas Muslim Indonesia Jl. Urip Sumoharjo No. km. 5, Panaikang, Panakkukang District, Makassar City, South Sulawesi 90231, Indonesia

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*) Corresponding author:
E-mail: dwinurmawanti557@gmail.com

ABSTRACT

Mulberry (*Morus alba* L.) is widely cultivated in Indonesia as silkworm feed and for leaf bioactive compounds, but propagation by cuttings is constrained by poor rooting and inconsistent establishment under suboptimal conditions. This study evaluated coconut water and bean sprout extract as natural plant growth regulators (PGRs) to improve mulberry cutting performance. The experiment was conducted in Paccerakang Village, Makassar (South Sulawesi, Indonesia) from April to June 2025 using a randomized block design with two factors: coconut water soaking (K0 control, K1 100 mL/L, K2 200 mL/L) and bean sprout extract soaking (T0 control, T1 50 g/L, T2 100 g/L, T3 150 g/L, T4 200 g/L). Stem cuttings (15–25 cm; 2–4 buds) were soaked for 30 min and planted in polybags with soil, goat manure, and rice husk charcoal (1:1:1). Coconut water at 200 mL/L accelerated shoot emergence (7.92 days) versus the control (9.58 days), while bean sprout extract at 200 g/L also hastened emergence (8.00 vs 10.78 days). At 7 days, the longest shoots occurred at 100 mL/L coconut water (29.10 cm) and 200 g/L bean sprout extract (30.12 cm). By 63 days, K1T1 produced the highest leaf number, K1T2 the highest shoot number, and 100 g/L bean sprout extract the greatest root distribution length. No significant interaction was detected, indicating independent effects. Both treatments therefore show practical potential for mulberry cutting propagation.

INTRODUCTION

Research on mulberry (*Morus alba* L.) is highly relevant given that this plant possesses significant economic value and broad benefits, particularly in the textile industry as the primary raw material for silk as well as a nutritious livestock feed (Acharya et al., 2022; Rahman & Islam, 2021). Success in mulberry cultivation is highly dependent on effective vegetative propagation, with the vegetative growth of cuttings serving as a key factor in determining the quality and quantity of the resulting plants (Baciu et al., 2023; Poonam et al., 2024). Therefore, efforts to enhance vegetative growth in mulberry cuttings have become an important focus in the development of more efficient cultivation technique (Sahu et al., 2025).

Natural plant growth regulators (PGRs) are increasingly being considered as environmentally friendly alternatives to synthetic chemicals, which have the potential to cause negative impacts on the environment and human health (Kumar et al., 2024). Coconut water and bean sprout extract are two natural substances known to contain plant hormones such as cytokinins and auxins (Carganilla et al., 2025). These hormones play a crucial role in stimulating plant growth and development processes, particularly in enhancing shoot and leaf formation as well as accelerating root growth in cuttings (Iqbal et al., 2024).

Although the potential of both natural substances as PGRs has been widely recognized, their specific use on mulberry cuttings has not been extensively studied (Ali et al., 2025). Existing research remains limited and has yet to provide a comprehensive overview of the effectiveness of coconut water and bean sprout extract in supporting vegetative growth of mulberry (Forsan et al., 2025). Therefore, a systematic study is needed to evaluate the effects of these two natural compounds in the context of mulberry cultivation, so as to offer a more sustainable and safer management alternative (Bai et al., 2023).

This study aims to evaluate the effects of coconut water and bean sprout extract administration as

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natural plant growth regulators on the vegetative growth of mulberry cuttings. The main objective of the research is to determine the influence of these two substances in enhancing growth parameters such as shoot length, number of leaves, and plant dry weight. The results of this study are expected to provide a scientific basis for the use of coconut water and bean sprout extract as effective and environmentally friendly PGR alternatives in mulberry cultivation.

MATERIALS AND METHODS

The research was conducted in Paccerakang Village, Biringkanaya District, Makassar City, South Sulawesi Province, from April to June 2025. The equipment utilized in this study included a scoop, label, ruler, scale, measuring cup, sieve, container, and stationery. The materials comprised mulberry stem cuttings (NI variety), coconut water, bean sprout extract, 18 cm x 18 cm polybags, soil, goat manure, burnt rice husks, and water.

The study employed a Randomized Block Design (RBD) with a two-factorial pattern. The first factor, coconut water administration, involved three treatment levels: K0 = Control, K1 = Soaking in coconut water at 100 ml/L of water, and K2 = Soaking in coconut water at 200 ml/L of water. The second factor, bean sprout extract administration, included five treatment levels: T0 = Control, T1 = Soaking in bean sprout extract at 50 g/L of water, T2 = Soaking in bean sprout extract at 100 g/L of water, T3 = Soaking in bean sprout extract at 150 g/L of water, and T4 = Soaking in bean sprout extract at 200 g/L of water.

The growing medium consisted of soil, goat manure, and rice husk charcoal in a 1:1:1 ratio, placed in 18 cm x 18 cm polybags. The medium was watered until saturation and allowed to settle until reaching field capacity. Cuttings were initiated by selecting a healthy, productive parent tree (3-5 years old), free from pests, and exhibiting good vigor. Branches measuring 15-25 cm in length with 2-4 bud nodes were selected. The base of the cutting was angled to enhance absorption, while the top was cut flat to minimize evaporation. The cuttings were sourced from East Luwu.

Bean sprout extract was prepared by blending 1 kg of bean sprouts with 1 liter of distilled water and 30 grams of granulated sugar, followed by filtration through cheesecloth and fermentation for two weeks in a closed container. Coconut water was obtained from young coconuts and filtered into a clean container using a sieve to ensure cleanliness and remove impurities. Mulberry stem cuttings were soaked for 30 minutes according to the concentration of coconut water and bean sprout extract treatments. The treated mulberry cuttings were planted upright in polybags containing pre-watered planting media and arranged in rows.

Plant maintenance involved watering and weed control. Watering was conducted twice daily, in the morning and evening, with the amount adjusted according to the plant's needs based on weather conditions and the moisture level of the growing medium. Weed control was performed manually by removing weeds growing around the plants.

RESULTS AND DISCUSSION

1. Time of Shoot Emergence

Table 1 displays the mean duration for the emergence of mulberry shoots after treatment with natural plant growth regulators, namely coconut water and bean sprout extract, as observed over a 7-day period.

Table 1. Mean Time for Mulberry Shoots to Appear in Treatment with Natural Plant Growth Regulators Coconut Water and Bean Sprouts Extract (7 days)

Coconut water growth regulator (K)	ZPT bean sprout extract (T)					Mean	HSD 0.05
	Control (T0)	50 g/L water (T1)	100 g/L water (T2)	150 g/L water (T3)	200 g/L water (T4)		
Control (K0)	12.33	10.33	9.67	9.33	9.00	9.58^{a}	
100 ml/L water (K1)	10.33	10.00	9.33	8.67	8.33	9.08^{ab}	1.51
200 ml/L water (K2)	9.67	9.00	8.33	7.67	6.67	7.92^{b}	
Mean	10.78^{a}	9.78^{abc}	9.11^{bcd}	8.56^{cd}	8.00^{d}		
HSD 0.05			1.29				

Note : Means followed by the same letter in the same row or column are not significantly different at the 5% level according to the HSD test.

The analysis of Table 1, conducted using the 5% HSD test, reveals that coconut water and bean sprout extract, when used as plant growth regulators (PGRs), significantly affect shoot emergence time, with variations dependent on concentration.

In the coconut water PGR treatment, the most rapid shoot emergence was recorded at 7.92 days with a concentration of 200 ml/L (K2), which was statistically faster than the untreated control (K0) at 9.58 days. This finding indicates that a higher concentration of coconut water enhances the speed of shoot emergence. Conversely, the 100 ml/L treatment (K1) did not show a significant difference from either the untreated control or the 200 ml/L treatment, suggesting a threshold effect where the lower concentration is inadequate to significantly accelerate shoot emergence (Hasmayaputra et al., 2024; Kong et al., 2025). The prolonged emergence time in the absence of treatment underscores the stimulatory effect of coconut water PGR at optimal concentrations (Domingues Neto et al., 2024).

Regarding the bean sprout extract PGR treatment, the fastest shoot emergence was observed at 8.00 days with the 200 g/L water treatment (T4), which was significantly quicker than the untreated control (T0) at 10.78 days and the lower concentrations of 50 g/L (T1) and 100 g/L (T2) (Ramadhanti et al., 2024). It is noteworthy that the 200 g/L water treatment (T4) did not differ significantly from another 200 g/L treatment (T3), indicating consistency in the effect at this concentration (Kry et al., 2021). This pattern illustrates that higher concentrations of bean sprout extract similarly expedite shoot emergence, whereas lower concentrations do not significantly enhance emergence time compared to no treatment (Dola et al., 2025).

Overall, these results suggest that both coconut water and bean sprout extract PGRs effectively reduce shoot emergence time when applied at sufficiently high concentrations. The absence of significant differences at lower concentrations indicates a dose-dependent response, highlighting the necessity of optimizing PGR concentration for maximum efficacy. The extended emergence times in untreated controls further emphasize the beneficial role of these natural PGRs in accelerating early plant development stages (Gupta et al., 2023).

2. Shoot Length

Table 3 displays the Mean length of mulberry plant shoots following a 7-day treatment period with natural plant growth regulators sourced from coconut water and bean sprout extract. These data demonstrate the impact of these treatments on shoot elongation in mulberry plants.

Table 3. Mean Length of Mulberry Plant Shoots in Natural Plant Growth Regulator Treatment of Coconut Water and Bean Sprouts Extract (7 days)

Coconut water growth regulator (K)	ZPT bean sprout extract (T)					Mean	HSD 0.05
	Control (T0)	50 g/L Water (T1)	100 g/L Water (T2)	150 g/L Water (T3)	200 g/L Water (T4)		
Control (K0)	16.72	18.66	20.46	26.88	27.69	23.42^{b}	
100 ml/L Water (K1)	24.70	25.53	29.78	29.93	31.17	29.10^{a}	4.87
200 ml/L Water (K2)	22.85	23.63	23.78	25.47	31.50	26.10^{b}	
Mean	21.42^{d}	22.61^{d}	24.67^{bcd}	27.43^{b}	30.12^{a}		
HSD 0.05			4.16				

Note : Means followed by the same letter in the same row or column are not significantly different at the 5% level according to the HSD test.

The results of the 5% HSD test for the coconut water PGR treatment reveal that the 100 ml/L concentration (K1) yielded the longest shoots, with an Mean length of 29.10 cm. This length was statistically comparable to both the control (K0) and the higher concentration of 200 ml/L (K2). These findings suggest that increasing the concentration beyond 100 ml/L does not significantly enhance shoot elongation, indicating a potential saturation point in the physiological response to coconut water PGR (Kafle et al., 2023). The similar Mean length of the shortest shoot at 23.42 cm in the control treatment (K0) further underscores that moderate concentrations of coconut water may optimize shoot growth without adversely affecting the shorter shoots.

Conversely, the bean sprout extract PGR treatment exhibited a different pattern, with the highest concentration tested (200 g/L, T4) significantly increasing the Mean length of the longest shoot to 30.12 cm compared to lower concentrations and the control (Yirmibeş et al., 2025). This suggests a dose-dependent response up to 200 g/L, with the 150 g/L concentration (T3) showing no significant difference from the highest dose, indicating that the growth-promoting effect plateaus near this range (Shamir et al., 2023). The shortest shoot length observed in the control (T0) highlights the overall stimulatory effect of bean sprout extract on shoot elongation, likely due to bioactive compounds that enhance cell division and elongation (Confraria et al., 2022).

The differential responses between the two PGR sources may be attributed to their distinct biochemical compositions (Khan et al., 2024). Coconut water contains natural cytokinins and other growth-promoting substances, which may have an optimal concentration range for efficacy, beyond which no additional benefit is observed (Shi et al., 2025). In contrast, bean sprout extract might contain a broader or more potent array of growth regulators or nutrients that sustain shoot elongation at higher concentrations. This difference underscores the importance of tailoring PGR type and concentration to the specific physiological responses desired in plant growth experiments (Anggarani et al., 2025).

Overall, these findings highlight the nuanced effects of PGR treatments on shoot growth, where both the source and concentration critically influence outcomes. The plateau in shoot length at higher concentrations for both PGRs suggests that excessive application may not yield proportional benefits and could potentially waste resources or induce stress responses. Future studies should explore the underlying molecular mechanisms driving these responses and assess the long-term effects of these PGR treatments on overall plant development and productivity (Chougule & Rawat, 2024).

3. Number of Leaves

Figure 1 depicts the mean quantity of mulberry plant leaves recorded after a 63-day treatment period with natural plant growth regulators sourced from coconut water and bean sprout extract.

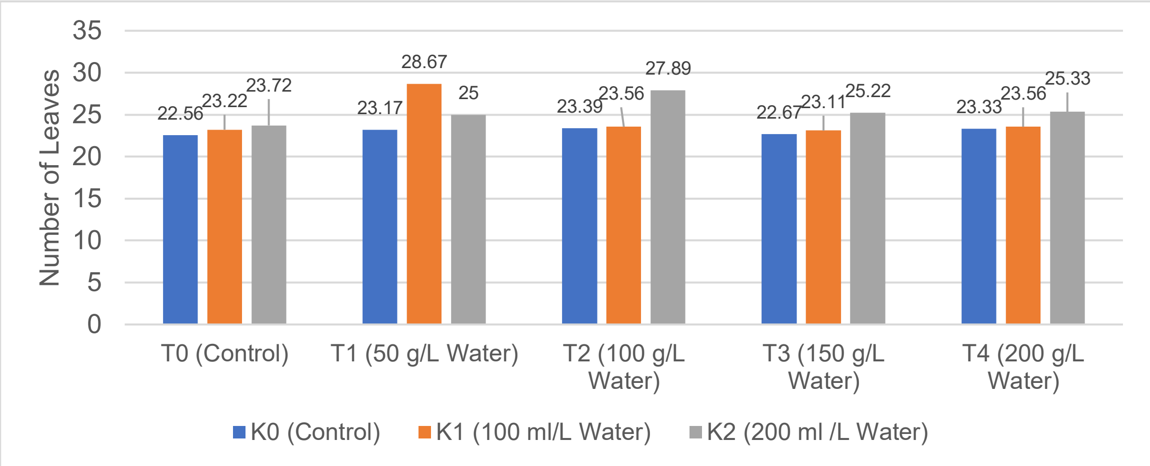

Figure 1. Mean Number of Mulberry Plant Leaves in Natural Plant Growth Regulator Treatment of Coconut Water and Bean Sprouts Extract (63 days)

The data depicted in Figure 1 demonstrates the substantial effect of the K1T1 treatment on leaf production, with an Mean of 28.67 leaves, which surpasses the other treatments. This indicates that the combination of factors represented by K1 and T1 synergistically enhances vegetative growth, possibly through improved nutrient availability, optimal environmental conditions, or effective treatment application (Radulov et al., 2025). The increased leaf count under this treatment may reflect enhanced photosynthetic capacity and overall plant vigor, which are essential for maximizing biomass accumulation and crop yield (Mominovna, 2023).

In contrast, the K0T0 treatment exhibited the lowest Mean number of leaves, 22.56, highlighting the restrictive impact of either the absence or minimal application of the critical variables K and T (Hu et al., 2022). This baseline treatment likely indicates suboptimal growth conditions, where nutrient deficiencies or environmental stressors limit leaf development. A reduction in leaf number can hinder the plant's capacity to capture light energy and synthesize carbohydrates, thereby restricting growth and productivity (Ye et al., 2022). The disparity between the K1T1 and K0T0 treatments underscores the significance of these factors in promoting healthy plant development (Mishra et al., 2025).

The variation in leaf number between the highest and lowest treatments offers insight into the plant species' responsiveness to management practices or experimental interventions (Stotz et al., 2022). The increase of approximately six leaves observed in the K1T1 treatment compared to K0T0 demonstrates the potential benefits of targeted interventions (Singh et al., 2023). This difference warrants further analysis to elucidate the underlying physiological or biochemical mechanisms, such as nutrient uptake efficiency, hormonal regulation, or stress mitigation, which collectively enhance leaf proliferation (Wang et al., 2025).

The findings presented herein have significant practical implications for the optimization of agricultural practices (Biswas et al., 2024). By determining the treatment combination that enhances leaf production, researchers and practitioners can adjust fertilization, irrigation, and other cultural practices to replicate these conditions. This strategy not only promotes sustainable crop management but also provides valuable insights for breeding programs focused on developing varieties with enhanced growth responsiveness. Future research should investigate the long-term effects of these treatments on yield components, stress resilience, and overall plant health to formulate comprehensive recommendations (Villalobos-López et al., 2022).

4. Leaf Widht

Table 4 presents the Mean leaf width of mulberry plants subjected to treatment with natural growth regulators, specifically coconut water and mung bean sprout extracts, over a period of 63 days.

Table 4. Mean Leaf Width of Mulberry Plants in Natural Plant Growth Regulator Treatment of Coconut Water and Bean Sprouts Extract (63 days)

Coconut water growth regulator (K)	**ZPT bean sprout extract (T)**					**Mean**	**HSD 0.05**
	Control (T0)	50 g/L Water (T1)	100 g/L Water (T2)	150 g/L Water (T3)	200 g/L Water (T4)		
Control (K0)	4.43	4.76	5.09	5.39	5.87	5.28[b]	
100 ml/L Water (K1)	5.94	6.13	6.51	6.47	6.31	6.36[a]	0.93
200 ml/L Water (K2)	6.20	6.30	6.41	6.39	5.77	6.22[a]	
Mean	5.53	5.73	6.00	6.08	5,98		

Note : Means followed by the same letter in the same row or column are not significantly different at the 5% level according to the HSD test.

According to the 5% HSD test results presented in Table 4, the treatment involving 100 ml/L water with PGR (K1) yielded the greatest Mean leaf width of 6.36. This measurement was significantly larger than that observed in the treatment without PGR (K0). These findings imply that the application of PGR at this concentration enhances leaf expansion compared to the absence of a growth regulator (Parmoon et al., 2022). The marked difference between K1 and K0 underscores the efficacy of PGR in increasing leaf width, possibly through the promotion of cell division or elongation processes .

The leaf width in the 100 ml/L treatment (K1) was not significantly different from that in the 200 ml/L water treatment with PGR (K2). This finding suggests that increasing the PGR concentration beyond 100 ml/L does not further augment leaf width. The observed plateau effect indicates that 100 ml/L may be close to the optimal concentration for maximizing leaf width, as higher doses do not yield additional benefits. This also implies a threshold beyond which PGR application does not enhance leaf growth, potentially due to physiological saturation or inhibitory effects at elevated concentrations (Poonia et al., 2024).

The treatment without plant growth regulators (PGR), designated as K0, exhibited the lowest Mean leaf width of 5.28. This finding highlights the role of PGR in facilitating leaf expansion. The lack of PGR restricts the growth stimulus, leading to narrower leaves (Supraja et al., 2025). The comparison between K0 and treatments with PGR underscores the significance of growth regulators in altering plant morphology and enhancing desirable traits, such as leaf width, which can influence photosynthetic capacity and overall plant vigor (Nisha et al., 2025).

The data indicate that the application of PGR at a concentration of 100 ml/L significantly increases leaf width compared to untreated controls. However, increasing the concentration to 200 ml/L does not result in further significant enhancement. These results imply that moderate concentrations of PGR are adequate for achieving optimal leaf growth, suggesting that excessive application may be superfluous. These insights are crucial for optimizing PGR use in agricultural practices, balancing efficacy with input costs (Greene, 2002).

5. Number of Shoots

Figure 2 illustrates the mean quantity of mulberry plant shoots produced following a 63-day treatment with natural growth regulators, specifically coconut water extract and mung bean sprouts.

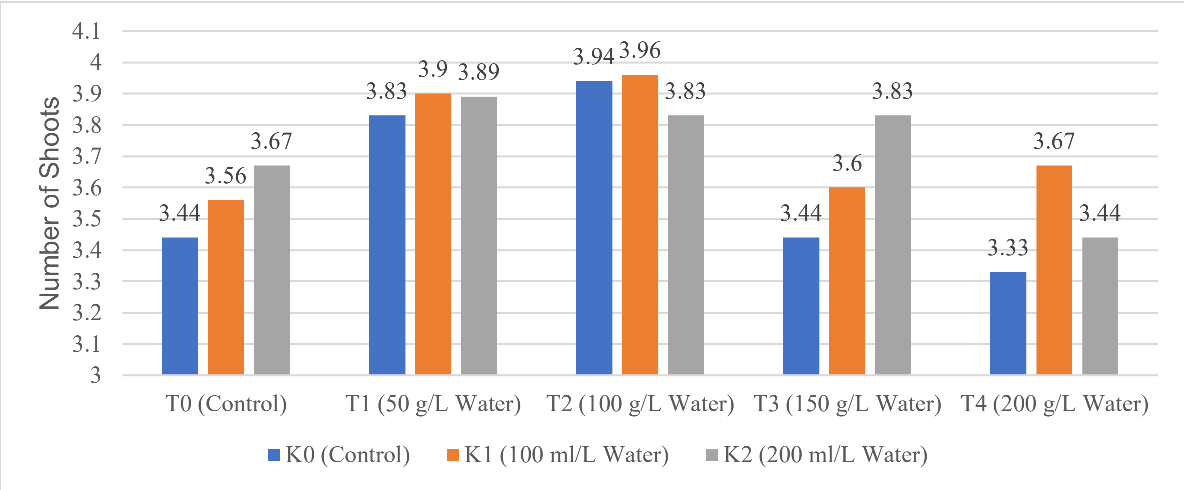

Figure 2. Mean Number of Mulberry Plant Shoots in Natural Plant Growth Regulator Treatment of Coconut Water and Bean Sprouts Extract (63 days).

Figure 2 demonstrates a distinct variation in shoot production among the different treatment groups. The K1T2 treatment group exhibited the highest Mean number of shoots, with a mean of 3.96, whereas the K0T4 treatment group showed the lowest Mean, at 3.33 shoots. This observation implies that the combination of factors represented by K1 and T2 provides the most conducive conditions for shoot proliferation. The increased shoot number in the K1T2 group may be attributed to an optimal balance of nutrients, growth regulators, or environmental conditions that promote cell division and differentiation in plant tissues (Kumari & Modgil, 2023).

Conversely, the K0T4 treatment, which resulted in the lowest Mean shoot production, likely indicates an unfavorable environment or suboptimal treatment parameters that restrict shoot induction or elongation. Factors contributing to the K0T4 outcome may include nutrient deficiency, inappropriate hormonal balance, or stress conditions that inhibit the regenerative capacity of the explants. This decrease in shoot number emphasizes the sensitivity of shoot development to specific treatment conditions and highlights the necessity of optimizing these parameters to enhance propagation efficiency (Raspor et al., 2021).

The variation in shoot Means between the highest and lowest values indicates the physiological responses elicited by the treatments. The K1T2 treatment appears to more effectively stimulate gene expression associated with shoot initiation and growth, potentially through enhanced signaling pathways involving auxins or cytokinins (Confraria et al., 2022). In contrast, the K0T4 treatment may not activate these pathways or might even trigger inhibitory signals, leading to diminished shoot formation. Investigating these molecular and biochemical mechanisms could offer valuable insights into optimizing tissue culture protocols for enhanced plant regeneration (Deep & Pandey, 2025).

These findings underscore the practical implications for large-scale propagation or breeding programs. Adopting the K1T2 treatment as a standard protocol could substantially enhance shoot yield, thereby decreasing the time and resources required per regenerated plant. In contrast, identifying the limitations of K0T4 aids in avoiding inefficient treatment combinations. Future research should investigate the specific components of K1T2 that contribute to its efficacy, facilitating targeted improvements and the potential integration of advantageous elements from various treatments to further augment shoot production (Wang et al., 2025).

6. Root Distribution Length

Table 5 presents the Mean length of mulberry root distribution following treatment with natural growth regulators, specifically coconut water and mung bean sprout extract, after a 63-day observation period.

Table 5. Mean Length of Root Distribution of Mulberry Plants in Natural Plant Growth Regulator Treatment Using Coconut Water and Bean Sprouts Extract (63 Days)

Coconut water growth regulator (K)	**ZPT bean sprout extract (T)**					**Mean**
	Control (T0)	50 g/L Water (T1)	100 g/L Water (T2)	150 g/L Water (T3)	200 g/L Water (T4)	
Control (K0)	16.70	19.79	20.07	17.89	17.62	18.84
100 ml/L Water (K1)	20.61	20.84	21.09	18.39	18.00	19.58
200 ml/L Water (K2)	19.54	20.28	21.07	18.61	18.28	19.56
Mean	18.95^{abc}	20.31^{a}	20.74^{a}	18.30^{bc}	17.97^{c}	
HSD 0.05			1.96			

Note : Means followed by the same letter in the same row or column are not significantly different at the 5% level according to the HSD test.

The data in Table 5 demonstrate that the 100 g/L water treatment (T2) resulted in the longest Mean root length of 20.74, which was significantly greater than the 17.97 Mean root length observed in the 200 g/L water treatment (T4). This finding implies that moderate water treatment concentrations enhance root elongation, potentially by optimizing water and nutrient availability or by modulating physiological responses conducive to root growth. The marked difference between T2 and T4 indicates that excessively high water treatment concentrations may inhibit root development.

The lack of significant differences between T2 and the treatments without plant growth regulators (T0), as well as the 50 g/L (T1) and 150 g/L (T3) water treatments, indicates a threshold effect wherein root growth is sustained within a specific range of water treatment concentrations. This observation suggests that low to moderate water concentrations do not significantly modify the root growth environment, thereby permitting relatively stable root elongation. Furthermore, it demonstrates that the application of plant growth regulators at these concentrations does not significantly impact root length compared to the control, potentially reflecting a balanced hormonal or osmotic environment favorable for root development (Voothuluru et al., 2024).

The significant reduction in root length observed at the highest concentration (200 g/L, T4) can be ascribed to osmotic stress or toxic effects resulting from the excessive concentration of water treatment. Elevated concentrations may lead to adverse conditions by diminishing water uptake efficiency or inducing metabolic imbalances within the root system. This decrease in root length under T4 treatment highlights the necessity of optimizing water treatment levels to prevent negative impacts on root morphology and overall plant health (Kou et al., 2022).

These findings underscore the significant influence of water treatment concentration on root system architecture. Specifically, an optimal concentration of 100 g/L (T2) promotes root elongation, which is crucial for the absorption of nutrients and water. In contrast, higher concentrations may hinder root growth. Comprehending these dynamics can guide agricultural practices and plant growth management, ensuring that water treatments are administered at levels that optimize root development without inducing stress or inhibition (Yan et al., 2023).

CONCLUSIONS

Coconut water at 200 ml/L accelerates bud emergence to 7.92 days, while 100 ml/L produces the greatest shoot length of 29.10 cm and leaf width of 6.36 cm, without significantly affecting leaf or shoot number or root length. Mung bean sprout extract at 200 g/L produces the greatest shoot length of 30.12 cm, whereas 100 g/L gives the highest root distribution length of 20.74 cm, with no significant effect on leaf or shoot number or leaf width. Their interaction does not significantly affect observed growth parameters, suggesting both natural plant growth regulators act independently and have potential as environmentally friendly alternatives for growth regulation in mulberry cutting propagation.

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