

Effect of Natural Growth Regulators on the Growth of Coffee Seedlings in the Cotyledon Phase

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ABSTRACT

Coffee is an important agricultural commodity with increasing global demand, so optimizing the growth of coffee seedlings, especially during the seedling phase, is crucial to increase productivity. The use of natural plant growth regulators offers an environmentally friendly and economical solution. This study aims to evaluate the effect of natural plant growth regulators from onion extract and bean sprout extract on the growth of robusta coffee seedlings (*Coffea canephora* L.) during the seedling phase. The study was conducted using a Randomized Block Design (RBD) with three treatments, namely control, onion extract, and bean sprout extract. The parameters measured included plant height, stem diameter, and number of leaves for six weeks. Data were analyzed using ANOVA and BNT test at the 5% level. The results showed that both natural plant growth regulators significantly increased the growth of coffee seedlings compared to the control. Bean sprout extract gave the best results for plant height (16.75 cm), while onion extract was superior in increasing stem diameter (4.65 mm) and number of leaves (12.20). Statistical analysis confirmed significant differences between treatments and controls for all parameters. Thus, the use of onion and bean sprout extracts as natural growth regulators has proven effective in increasing the growth of coffee seedlings in the seedling phase, offering an environmentally friendly and economical alternative for optimizing the growth of coffee seedlings.

INTRODUCTION

Coffee is one of the agricultural commodities that holds significant economic value and plays a crucial role in the global economy. As a widely consumed beverage worldwide, coffee has become an integral part of modern society's daily life. The

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coffee industry not only contributes substantially to the income of coffee-producing countries but also creates employment for millions along the production and distribution chain (Azmi & Handriatni, 2019; Hidayati & Subroto, 2018). Consequently, efforts to enhance the productivity and quality of coffee plants continue to be a

primary focus in the agricultural sector of various coffee-producing nations, including Indonesia.

In the global context, the demand for coffee continues to rise year after year. This trend is driven by various factors, including population growth, lifestyle changes, and an increasing appreciation for high-quality coffee. As demand increases, the challenges in coffee production are becoming increasingly complex (Rohman & Taufika, 2024; Sitinjak et al., 2022). Climate change, land degradation, and the emergence of new pests and diseases pose serious threats to the sustainability of the coffee industry. This situation necessitates innovation and new approaches in coffee cultivation to ensure a stable and sustainable supply.

One of the critical aspects in coffee production is the nursery phase. The quality of coffee seedlings has a direct influence on the productivity and resilience of coffee plants in the future. Healthy and strong seedlings will produce plants that are more productive and resistant to various environmental pressures (Nugroho et al., 2023). Given the importance of this early stage, optimizing the growth of coffee seedlings has become a strategic focus in efforts to increase overall coffee production.

To address the challenges in coffee production and improve nursery practices, various methods and technologies have been developed. Among these, the use of plant growth regulators (PGRs) has emerged as a promising approach. PGRs have long been recognized as crucial factors in enhancing plant growth and development. These compounds play a vital role in regulating various plant physiological processes, from cell division and elongation to tissue differentiation (Abror & Dwi Noviyanti, 2019; Debitama et al., 2022; Ernita et al., 2023).

In the context of coffee breeding, the application of appropriate PGRs can yield significant benefits. These include accelerating growth, improving seedling uniformity, and increasing resistance to environmental stress. By optimizing these early-stage processes, coffee growers can potentially enhance the overall quality and productivity of their crops.

However, it's important to note that the use of synthetic PGRs is not without challenges. There are growing concerns regarding their environmental

and health impacts, as well as the relatively high production costs associated with their use (Azmi & Handriatni, 2019; Didi et al., 2022; Febri Arif Cahyo Wibowo et al., 2020). These concerns have led researchers and coffee producers to explore alternative approaches that can achieve similar growth-enhancing effects while mitigating potential drawbacks.

In line with the global trend towards sustainable and environmentally friendly agriculture, attention is now turning to the use of natural PGRs derived from organic materials. Natural PGRs have several advantages compared to synthetic PGRs, including being safer for the environment, cheaper, and easily accessible to small farmers. (Kamillia et al., 2019; Khaleghi et al., 2021; Kresnawaty et al., 2022). Two promising natural sources of ZPT and the focus of this research are onion extract and bean sprout extract.

In the search for alternative, natural plant growth regulators (PGRs) for coffee seedling cultivation, researchers have begun exploring the potential of various plant-based extracts. However, there remains a significant gap in our understanding of how these natural extracts, particularly those derived from onions and bean sprouts, affect coffee seedlings. While these extracts have shown promise in other plant species, their efficacy and optimal application in coffee nurseries are yet to be fully explored.

Onions have long been known to have various benefits, not only as a food ingredient but also in agriculture. Onion extract contains various bioactive compounds, including phytoin and gibberellin, which play an important role in cell elongation and cell division (Ndruru et al., 2022). In addition, onions are also rich in sulfur and phenolic compounds that can increase plant resistance to disease. The use of onion extract as a natural PGR has shown promising results in various types of plants, but its application to coffee seedlings still requires further research to determine its specific effects and optimal usage in this context.

On the other hand, bean sprouts or mung bean sprouts are also known to have potential as a source of natural PGRs. The germination process in bean sprouts produces various enzymes and growth hormones, especially gibberellins and cytokinins, which play a role in stimulating plant growth and development. Bean sprout extract has been proven effective in increasing seed

germination and seedling growth in several types of plants (Asmono et al., 2023). However, like onion extract, the effectiveness of bean sprout extract on coffee seedlings, especially in the seedling phase, still needs to be explored further.

The existing literature lacks comprehensive studies on how these natural extracts interact with coffee seedlings' specific physiological processes, their optimal concentrations for application, and their long-term effects on coffee plant development and productivity. This gap in knowledge presents an opportunity for research that could potentially revolutionize sustainable coffee nursery practices.

The cotyledon phase is a critical stage in the growth of coffee seedlings. In this phase, coffee seedlings begin to develop the first pair of oval-shaped leaves, known as cotyledons. Optimal growth in this phase is very important because it will determine the quality of coffee seedlings in the next stage. (Kurniati et al., 2019; Mariana et al., 2023; Muhyidin et al., 2020; Sitingjak et al., 2022). Factors such as seedling height, stem diameter, and number of leaves are important indicators in assessing the health and vigor of coffee seedlings in the seedling phase.

Seedling height is an indicator of vertical growth that reflects the ability of plants to access light and nutrients. Seedlings that grow to optimal height will have an advantage in competing with weeds and have better production potential in the future. Meanwhile, stem diameter is an indicator of seedling strength and stability. Thicker stems generally indicate stronger seedlings and are more resistant to environmental stress such as wind and heavy rain. Finally, the number of leaves is closely related to the photosynthetic ability of plants. The more healthy leaves, the higher the seedling's ability to produce energy for growth and development.

In the context of this study, the main focus is to explore the effect of natural PGRs, especially onion extract and bean sprout extract, on the three growth parameters in coffee seedlings in the kepelan phase. The hypothesis underlying this study is that the application of natural PGRs can significantly increase the growth of coffee seedlings compared to the control without PGR treatment.

Several previous studies have shown the potential of using natural growth regulators to increase the growth of plant seedlings, including coffee. Research conducted by Sasmita et al. (2019) demonstrated that the application of shallot extract at a concentration of 60% can significantly increase the growth of Arabica coffee seedlings, especially in terms of plant height and number of leaves. Meanwhile, a study conducted by Putri et al. (2020) showed that bean sprout extract at a concentration of 30% was effective in accelerating root growth and increasing the vigor of Robusta coffee seedlings.

In a broader context, the use of natural plant growth regulators has received increasing attention in the field of sustainable agriculture. According to a review conducted by Sharma et al. (2021), the use of plant extracts as biostimulants can increase plant tolerance to abiotic stress and improve nutrient utilization efficiency. This is in line with the findings of Roupheal and Colla (2020) who highlighted the potential of plant extract-based biostimulants in improving the growth and productivity of horticultural crops.

More specifically on coffee plants, research by Martins et al. (2019) revealed that the application of natural plant growth regulators can increase not only the vegetative growth of coffee seedlings, but also increase chlorophyll content and antioxidant enzyme activity.

Although these studies have provided valuable insights, there is still a knowledge gap regarding the effectiveness of the combination of onion and bean sprout extracts as a natural growth regulator, especially in the seedling stage of coffee seedlings.

Considering all these aspects, this research on "The effect of plant growth regulators on the growth of coffee seedlings in the kepelan phase" is not only relevant from an agronomic perspective, but also has the potential for significant impact in socio-economic and environmental contexts.

MATERIALS AND METHODS

This research was conducted in the experimental garden of the Payakumbuh State Agricultural Polytechnic, Lima Puluh Kota Regency, West Sumatra, over a four-month period from April to August 2024. The study employed a Completely Randomized Design (CRD) with three treatment groups: onion extract, bean sprout extract (both at

50% concentration), and a control group (water application only). Each treatment was replicated five times with 20 seedlings per replication, resulting in a total of 300 coffee seedlings under observation.

The materials used included robusta coffee (*Coffea canephora* L.) seedlings in the cotyledon phase, cow manure, Urea fertilizer, and Dithane M-45 fungicide. The equipment utilized included saws, hoes, blenders, hand sprayers, digital calipers, and a lux meter. Land preparation involved creating beds measuring 3 meters by 1.25 meters, with drainage channels. Shade was provided using paranet and netting, allowing 70% light transmission. The planting medium consisted of a mixture of soil and manure in a 2:1 ratio. Environmental conditions were monitored throughout the experiment, with average daytime temperatures of 28°C ($\pm 2^\circ\text{C}$), relative humidity of 75% ($\pm 5\%$), and light intensity under the shade of 10,000 lux ($\pm 1,000$ lux).

Onion and bean sprout extracts were prepared by grinding 2 kg of fresh materials separately in 2 liters of distilled water (1:1 ratio) for 2 minutes using a commercial blender. The resulting mixtures were filtered through cheesecloth and diluted to a 50% concentration with distilled water. The pH of both extracts was adjusted to 6.5 using citric acid or sodium bicarbonate as needed. The extracts were freshly prepared before each application.

Treatment applications involved spraying 10 ml of the respective solution (onion extract, bean sprout extract, or water for the control group) per seedling. Applications were made three times at three-week intervals, starting when the seedlings reached the cotyledon phase. Maintenance activities included daily watering to field capacity, weeding as needed, and fertilization with Urea (1 g per seedling) every two weeks. Disease control was performed preventively with Dithane M-45 fungicide at a concentration of 2 g/L, applied bi-weekly.

Seedling growth was observed every two weeks on 5 randomly selected plants per replication (25% of the total sample). The parameters measured were plant height (cm), stem diameter (mm), and the number of leaves. Plant height was measured from the soil surface to the highest growing point using a ruler, stem diameter was measured 1 cm above the soil surface using digital calipers, and the

number of leaves was determined by counting fully expanded leaves.

Data were analyzed using analysis of variance (ANOVA) and the Least Significant Difference (LSD) test at a 5% significance level, with the help of SPSS software version 25 (Rohman & Taufika, 2024; Sapri & Febrialdi, 2021; Singh et al., 2012; Suman et al., 2017; Syamsiah & Marlina, 2024; Tamba et al., 2020). This study aimed to evaluate the effect of natural plant growth regulators derived from onion extract and bean sprout extract on the growth of robusta coffee seedlings (*Coffea canephora* L.) in the cotyledon phase, focusing on plant height, stem diameter, and the number of leaves as key growth indicators.

RESULTS AND DISCUSSION

This study aims to examine the effect of natural plant growth regulators, namely onion extract and bean sprout extract, on the growth of coffee seedlings in the kepelan phase. The kepelan phase is an important stage in the early development of coffee seedlings, where seedling height growth is the main indicator of successful growth. Natural plant growth regulators are believed to be able to increase plant growth in a more environmentally friendly way than synthetic plant growth regulators. In this study, treatments were given to coffee seedlings using two types of plant growth regulators, namely onion extract and bean sprout extract, as well as a control group that was not given any treatment.

1. The Effect of Natural Plant Growth Regulators on the Height of Coffee Seedlings in the Kepelan Phase

The height of the coffee seedlings was measured periodically to assess the effect of each treatment on the growth of the coffee seedlings. The growth of the height of coffee seedlings is one of the important parameters in evaluating the success of the use of natural growth regulators. In this study, the effect of onion and bean sprout extracts on the growth of the height of coffee seedlings was measured every week for six weeks. The results can be obtained as follows:

Table 1. Average Coffee Height (cm)

Observation (weeks after planting)	Control	Onion Extract	Bean Sprouts Extract
1	3.56	5.17	5.00
2	4.30	6.00	6.60
3	4.36	8.25	8.00
4	5.47	8.67	10.50
5	6.57	13.75	11.43
6	8.50	15.88	16.75

Based on table 1 above, it can be proven that in terms of plant height growth, the use of natural growth regulators also resulted in a significant increase. In the first week, the average height of coffee seedlings in the control group was only 3.56 cm, while the onion and bean sprout extract groups reached 5.17 cm and 5.00 cm, respectively. Until the sixth week, the control group grew to 8.50 cm, while the onion and bean sprout extract groups grew much higher, reaching 15.88 cm and 16.75 cm, respectively. This shows that bean sprout extract gives the best results in increasing the height of coffee seedlings, followed by onion extract. After that, hypothesis testing was carried out using analysis of variance (ANOVA) and BNT test at the 5% level which is shown as follows:

Table 2. BNT Test Results for Coffee Height

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	301.201	2	150,600	30,176	0.000
Intercept	4,989,720	1	4,989,720	999,803	0.000
Treatment	301.201	2	150,600	30,176	0.000
Error	134,749	27	4,991		
Total	5,425,670	30			
Corrected Total	435,950	29			

From the data analysis using the Between-Subjects Effects test, it was found that there was a significant effect of the treatment of plant growth regulators on the height of coffee seedlings. The test results showed that the model used was able to explain 69.1% of the variability in the height of coffee seedlings, with an Adjusted R Squared value of 66.8%. This indicates that the plant growth

regulators used have a significant impact on the growth of the height of coffee seedlings in the kepelan phase.

The results of statistical analysis showed that the treatment of onion extract and bean sprout extract significantly affected the growth of coffee seedlings ($p = 0.000$). The F value for the treatment variable was 30.176, which means that the difference in treatment had a significant effect on the growth of coffee seedlings. The average height of coffee seedlings treated with onion extract and bean sprout extract showed a more significant increase compared to the control group.

The results of this study are in line with the initial assumption that natural growth regulators, especially onion extract and bean sprout extract, can accelerate the growth of coffee seedlings. Onion extract is known to contain active compounds such as amino acids and natural phytohormones that can stimulate plant growth. Likewise, bean sprout extract contains enzymes and other natural growth regulators that function to accelerate cell division in plants, thereby accelerating the growth of coffee seedlings. (Asmono et al., 2023; Ndruru et al., 2022).

This study also revealed that the group of coffee seedlings treated with natural growth regulators showed better growth results compared to the control group, which was not given any treatment. This shows that the use of natural growth regulators such as onion extract and bean sprout extract can be an effective and environmentally friendly alternative in increasing the growth of coffee seedlings. Overall, this study concluded that natural growth regulators, especially onion extract and bean sprout extract, have a significant positive impact on the growth of coffee seedlings in the kepelan phase.

2. The Effect of Natural Plant Growth Regulators on Coffee Stem Diameter in the Kepelan Phase

In addition to plant height, stem diameter is also an important indicator to measure the strength and stability of coffee seedlings during their growth. The effect of natural growth regulators on increasing stem diameter was also observed regularly for six weeks which can be described in the following table 3:

Table 3. Average Coffee Stem Diameter (mm)

Observation (weeks after planting)	Control	Onion Extract	Bean Sprouts Extract
1	1.00	2.10	2.43
2	1.06	2.25	2.97
3	1.12	3.01	3.38
4	1.16	3.70	3.83
5	1.96	1.16	3.99
6	2.37	4.65	4.16

Based on the average coffee stem diameter data for six weeks, it can be seen that treatment with natural growth regulators such as onion extract and bean sprout extract has a significant effect on increasing the diameter of the coffee stem compared to the control group. In the first week, the diameter of the coffee stem in the control group only reached 1.00 cm, while the onion and bean sprout extract groups reached 2.10 cm and 2.43 cm, respectively. This difference was increasingly visible in the following weeks. In the sixth week, the control group only reached a diameter of 2.37 cm, while the groups given onion and bean sprout extract reached 4.65 cm and 4.16 cm, respectively. After that, hypothesis testing was carried out using analysis of variance (ANOVA) and BNT test at the 5% level which is shown as follows:

Table 4. BNT Test Results for Coffee Stem Diameter

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	22.190	2	11,095	33.21	0.00
Intercept	384,850	1	384,850	1,151,95	0.00
Treatment	22.190	2	11,095	33.21	0.00
Error	9.020	27	0.334		
Total	416,061	30			
Corrected Total	31,210	29			

The results of data analysis from the Between-Subjects Effects test showed that natural growth regulators, both onion extract and bean sprout extract, had a significant effect on the growth of coffee seedling stem diameter. Based on the F value of 33.210 with a significance level of $p =$

0.000, it was proven that the difference in treatment had a significant effect on the diameter of coffee seedling stems during the kepelan phase. This shows that the use of natural growth regulators contributes to an increase in the thickness of coffee seedling stems, which is one of the signs of healthy and well-developed coffee seedlings.

From the determination coefficient value (R Squared) of 0.711 and Adjusted R Squared of 0.690, it can be concluded that this research model is able to explain about 71.1% of the variability of coffee seedling stem diameter growth. This shows that natural growth regulators play an important role in influencing this variable, with a fairly strong effect.

Specifically, the treatment group that received onion extract and bean sprout extract showed a more significant increase in stem diameter compared to the control group. Onion extract is known to contain bioactive compounds that can stimulate cell division and elongation in plant stems, thereby encouraging an increase in stem thickness. Meanwhile, bean sprout extract contains natural hormones and enzymes that also play a role in increasing plant cell growth, which has a positive impact on the diameter of coffee seedling stems.

In addition, the results of the analysis show that the corrected model produces a Sum of Squares value of 22,190 with a Mean Square of 11,095. Meanwhile, the error or variability that cannot be explained by the model is relatively small, which is 9,020 with a Mean Square of 0.334. This shows that the model used is quite good at explaining the effect of treatment on the diameter of coffee seedling stems.

Overall, the results of this study support the initial hypothesis that natural plant growth regulators, especially onion extract and bean sprout extract, can provide a significant positive impact on the growth of coffee seedlings in the kepelan phase, especially in terms of stem diameter. With a larger stem diameter, coffee seedlings are expected to be stronger and have better growth potential in subsequent phases.

3. The Effect of Natural Plant Growth Regulators on the Number of Coffee Leaves in the Kepelan Phase

The number of leaves on coffee seedlings is another indicator that reflects the effectiveness of natural plant growth regulators in supporting the photosynthesis process and overall plant health. In this study, the number of leaves was measured every week to see how the onion and bean sprout extract treatments affected the formation of new leaves as described in the following table:

Table 5. Average Number of Coffee Leaves

Observation (weeks after planting)	Control	Onion Extract	Bean Sprouts Extract
1	2.00	2.00	2.00
2	2.50	2.00	4.20
3	3.00	4.40	6.60
4	4.25	8.67	7.80
5	5.00	10.80	9.60
6	5.00	12.20	10.80

The leaf number data also showed a positive effect of onion and bean sprout extract treatments on increasing the number of leaves in coffee seedlings. In the first week, all groups had the same number of leaves, which was 2 leaves per seedling. However, in the following weeks, there was a more significant increase in the number of leaves in the group treated with plant growth regulators. In the sixth week, the onion extract group showed the highest results with 12.20 leaves, followed by the bean sprout extract group with 10.80 leaves. Meanwhile, the control group only had 5.00 leaves. This increase in the number of leaves indicates that natural plant growth regulators encourage the formation of new leaves, which play an important role in the process of photosynthesis and the overall growth of coffee seedlings. After that, hypothesis testing was carried out using analysis of variance (ANOVA) and BNT test at the 5% level which is shown as follows:

Table 6. BNT Test Results for Coffee Leaf Count

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	163,40	2	81,70	28,54	0.00
Intercept	2,940,30	1	2,940,30	1,027,01	0.00
Treatment	163,40	2	81,70	28,54	0.00
Error	77,30	27	2,86		
Total	3,181,00	30			
Corrected Total	240,70	29			

From the results of the Between-Subjects Effects test, it was found that natural growth regulators, both onion extract and bean sprout extract, significantly affected the number of leaves in coffee seedlings. The F value of 28.537 with a significance level (p-value) of 0.000 indicates that the treatment had a significant effect on increasing the number of leaves in coffee seedlings. In other words, the use of onion extract and bean sprout extract substantially affected the development of coffee seedling leaves during the kepelan phase.

The results of the analysis show that the Corrected Model has a Sum of Squares value of 163,400 and a Mean Square of 81,700, which indicates a large contribution from the treatment to the number of leaves variable. In addition, the error or variability that cannot be explained by the model is relatively small, namely with a Sum of Squares value of 77,300 and a Mean Square of 2,863. This shows that the model used is quite effective in explaining the relationship between treatment and the number of leaves of coffee seedlings.

The R Squared value of 0.679 indicates that this research model is able to explain about 67.9% of the variability in the number of leaves in coffee seedlings, with an Adjusted R Squared value of 0.655. This figure indicates that natural growth regulators have a significant effect on increasing the number of leaves in coffee seedlings, while the rest is explained by other factors not included in the model.

Specifically, the treatment groups receiving onion extract and bean sprout extract showed a greater number of leaves compared to the control group. Onion extract is known to contain active substances such as amino acids and natural phytohormones that play a role in accelerating leaf growth. Likewise, bean sprout extract contains natural hormones and enzymes that can stimulate the cell division process, thus contributing to a significant increase in the number of leaves.

The results of this study indicate that treatment with natural growth regulators can significantly increase the number of leaves in coffee seedlings. Coffee seedlings treated with onion and bean sprout extracts grew better in terms of the number of leaves than seedlings that were not treated. This is important because a greater number of leaves indicates a higher photosynthetic ability, which in turn will support overall plant growth.

Correlation of Three Variables

The application of natural growth regulators, specifically onion extract and bean sprout extract, demonstrated a significant positive effect on the growth of coffee seedlings in the cotyledon phase. Statistical analysis revealed consistent and substantial increases across all three measured growth parameters: plant height, stem diameter, and number of leaves.

Coffee seedlings treated with bean sprout extract exhibited the highest vertical growth, reaching 16.75 cm by the sixth week, followed closely by those treated with onion extract at 15.88 cm. In contrast, control seedlings only attained a height of 8.50 cm during the same period. This marked difference underscores the efficacy of natural growth regulators in promoting the vertical development of coffee seedlings.

Regarding stem diameter, onion extract proved most effective, resulting in a diameter of 4.65 mm by the sixth week. Seedlings treated with bean sprout extract showed a slightly smaller diameter of 4.16 mm, while control seedlings lagged significantly at 2.37 mm. This enhancement in stem diameter suggests that natural growth regulators

contribute to strengthening the structural integrity of coffee seedlings, a crucial factor for future plant resilience.

In terms of leaf development, onion extract again yielded the most impressive results, with treated seedlings averaging 12.20 leaves by the sixth week. Bean sprout extract treatment led to an average of 10.80 leaves, while control seedlings developed only 5.00 leaves. This substantial increase in leaf number is particularly significant as it directly correlates with the plant's photosynthetic capacity, which in turn supports overall seedling growth and development.

The effectiveness of onion and bean sprout extracts as natural growth regulators can be attributed to their rich content of bioactive compounds. Onion extract contains sulfur compounds and phytohormones such as auxins and gibberellins, which play crucial roles in cell elongation and division. Auxins, for instance, stimulate cell elongation by increasing cell wall plasticity and promoting the expression of specific genes involved in growth (Zhao, 2010). Gibberellins, on the other hand, enhance stem elongation by stimulating both cell division and elongation, particularly in young, developing tissues (Hedden & Sponsel, 2015).

Bean sprout extract is abundant in enzymes and natural growth hormones, particularly gibberellins and cytokinins. Cytokinins are known to promote cell division and differentiation, contributing to overall plant growth and development (Kieber & Schaller, 2018). The synergistic action of these hormones likely accounts for the observed enhancements in seedling growth parameters.

Moreover, recent studies have shown that the combination of different plant hormones can lead to more pronounced growth effects than individual hormones alone. For example, the interaction between auxins and cytokinins has been demonstrated to regulate various aspects of plant development, including root and shoot growth (Schaller et al., 2015). This synergistic effect may explain why the natural extracts, which contain a

complex mixture of growth-promoting compounds, showed such significant impacts on seedling growth.

These findings suggest that the use of natural plant growth regulators can serve as an effective and environmentally friendly alternative for enhancing the growth of coffee seedlings in the cotyledon phase. Beyond improving growth parameters, this approach aligns with sustainable agriculture principles and may reduce reliance on synthetic plant growth regulators, which are often more expensive and potentially harmful to the environment. Future research could focus on optimizing extract concentrations and application methods to further maximize the benefits of these natural growth regulators in coffee seedling cultivation.

CONCLUSIONS

This study revealed that the use of natural plant growth regulators in the form of onion extract and bean sprout extract had a significant positive effect on the growth of coffee seedlings at the kepel phase. Both treatments consistently increased plant height, stem diameter, and number of leaves of coffee seedlings compared to the control. Bean sprout extract showed the best results in increasing plant height, while onion extract was superior in increasing stem diameter and number of leaves. Statistical analysis confirmed the significance of the differences between treatments and controls for all parameters measured. These findings indicate that natural plant growth regulators can be an effective and environmentally friendly alternative to improve the growth of coffee seedlings. The use of onion and bean sprout extracts not only improved growth parameters but was also in line with the principles of sustainable agriculture. Further research is needed to optimize the concentration and application method of these natural plant growth regulators on a larger scale.

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