

Article

The effect of shoot growth from single stick rejuvenation with clipping treatment on branch growth of robusta coffee (*Coffea canephora* L.) BP308 clone

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Abstract: Robusta coffee (*Coffea canephora* L.) is the type of coffee most widely developed by farmers in Indonesia. The BP308 is a clone discovered by the coffee and cocoa research center which is included in the Robusta coffee clone which has a large and sturdy stature. One of the coffee plant maintenance activities that needs to be carried out is pruning so that coffee plant productivity can be optimal by removing old branches that are less productive and replacing them with young branches that are more productive. Pruning is a clipping, especially for plants that have difficulty growing reproductive branches. Clipping is carried out at the beginning of the rainy season so as not to stimulate the formation of flowers on the circumcised branches. The method used T-test calculations from the results of rejuvenation of single stems with treatment of one node and two nodes resulting from clipping on shoot growth and the data is then analyzed using a quantitative descriptive analysis method. The results show that there is no influence on shoot length parameters. However, it has a significant increase in the number of leaves from 1,47 to 2,33, and it has a significant increase in shoot diameter from 1,63 mm to 2,38 mm. This is the first study comparing single vs. double node clipping on BP308 clone under specific microclimate conditions.

Keywords: Branch growth, clipping, clones, rejuvenation

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1. Introduction

Pruning is one of the essential maintenance practices in coffee cultivation. It plays a crucial role in sustaining productivity and ensuring the long-term health of coffee plants. Proper pruning promotes vigorous, healthy growth and enhances the plant's resistance to pest infestations. Within the framework of integrated pest management, pruning serves as a cultural control method aimed at disrupting the life cycle of key coffee pests. Additionally, it involves the removal of old, unproductive, or pest- and disease-damaged branches, allowing nutrients to be redirected to younger, more productive growth. This practice ultimately supports the goal of maintaining optimal yields [1]–[3]. Recent research has identified beneficial bacteria from an exploration of coffee leaf litter to control plant diseases [4]–[7].

The coffee plant pruning system can be carried out using two approaches: single stem pruning and double stem pruning. In Indonesia, large plantation companies commonly favor the single stem method. This approach involves three stages of pruning: formative pruning, production pruning, and rejuvenation pruning [8]. Shape pruning is a trimming technique applied to plants that struggle to develop reproductive branches. This method involves removing any branches that emerge before the plant reaches a height of 1.5

meters, encouraging vertical growth and promoting a strong, upright structure [9]. The aim of shape pruning is to form the framework of the coffee tree so that the plant can grow strongly and in balance by forming plagiotropic branches, both primary and secondary branches [10]. Shape pruning involves two main activities: topping and clipping. Clipping is performed at the start of the rainy season to prevent flower formation on the pruned branches. It is done by cutting the branches approximately 15–20 cm from the main stem, or about two nodes away [11].

National coffee development has a positive impact on improving the community's economy. According to BPS, coffee production in Indonesia in 2021 reached 786.2 thousand tons, managed by 99.32% of Community Plantations (PR), 0.53% of Large State Plantations (PBN), and 0.15% of Large Private Plantations (PBS). Coffee production increased from 2019 to 2021. Coffee production in 2019 was 752.51 thousand tons increased 1.31% to 762.38 thousand tons in 2020. Coffee production in 2021 is estimated to increase 3.12% to 786.19 thousand tons. In 2021, large plantation (PB) coffee production was highest in East Java Province, reaching 4.23 tons or 79.52% of Indonesia's total large plantation (PB) coffee production. Meanwhile, the largest People's Plantation (PR) coffee production is in South Sumatra Province, namely 211.68 tons or 27.11% of People's Plantation (PR) production. Common coffee plant varieties that are widely cultivated include robusta coffee and arabica coffee.

Robusta coffee is a commodity that has strategic value in strengthening the national economy. The future of Indonesian coffee products is supported by the availability of land for coffee development, and Indonesia has geographical and climatic advantages to produce coffee whose taste and aroma are popular with people throughout the world [12]. At the beginning of the 20th century, Robusta coffee (*Coffea canephora* var. *Robusta*), which is resistant to leaf rust, began to be cultivated. Currently, many coffee plantations in Indonesia cultivate robusta coffee and have mass produced it [13]. Although BP308 is widely cultivated, the effects of single- vs double-node clipping on vegetative growth remain understudied. Therefore, This study was conducted to assess how clipping, by retaining either one or two nodes, influences branch growth in the Robusta coffee BP308 clone."

2. Materials and Methods

The research was conducted from June to November 2023 and took place at the 6-year-old BP308 Robusta Coffee Plant Collection Garden, Jember State Polytechnic. The tools and materials used were scales, saws, pruning shears, knapsacks, cameras, machetes, sickles, hoes, water hoses, watering cans, herbicide, urea, SP36, and KCL fertilizer. The statistical research used the T-test with the cases raised, namely comparing the growth of shoots from treated branches *clipping* leaving 1 node and 2 nodes. Number of plants are 30 plants per treatment with characteristic 30-year-old BP308 Robusta coffee plants.

The observed parameters are:

- a. Shoot length (cm). Observe the growth of shoot length by measuring the length of shoots growing in the leaf axils on branches that have been circumcised or *clipping* by using a ruler. Observations were carried out once a month after 1 month of pruning activities.
- b. Number of leaves (pairs). Make observations to count the number of pairs of leaves by counting the number of pairs of leaves from shoots growing in the leaf axils of branches that have been circumcised or clipping. Observations of the number of pairs of leaves were carried out once a month after 1 month of pruning activities.
- c. Shoot diameter (mm). Observe shoot diameter by measuring the diameter of shoots growing in the leaf axils of branches that have been circumcised or *clipping* using a caliper. Shoot diameter observations were made on the last two observations.

The supporting parameters observed:

- Temperature. The measurements are carried out using thermometer room (°C). Measurements are carried out twice a week, every Wednesday and Saturday in the morning between 07.00 – 09.00 WIB.
- Humidity. The measurements are carried out using the application weather on smartphone. The humidity value is expressed in units (%). Measurements are carried out twice a week, every Wednesday and Saturday in the morning between 07.00 – 09.00 WIB.
- Light Intensity. Light intensity measurements were conducted using the *Illuminance – Lux Light Meter* application installed on a smartphone. The results were recorded as percentage (%) values. Measurements were taken twice weekly during the final (fifth) week of observation, specifically on Wednesdays and Saturdays, between 07:00 and 09:00 WIB.

3. Results and Discussion

The results of the T-test analysis indicated no significant differences in shoot length parameters across the first to fifth observations. For the parameters of the number of leaf pairs and shoot diameter, no significant differences were observed from the first to fourth observations. However, the fifth observation revealed statistically significant differences for both parameters (Table 1).

Table 1. Summary of T Test Results Parameters of Shoot Length, Number of Leaf Pairs, and Diameter

and Diameter							
Parameter Observation	T-Test					T-Table	
	Month						
	1	2	3	4	5	5%	1%
Shoot Length	1,27ns	0,96 ns	0,66 ns	0,85 n	1,05 ns	2,048	2,763
Number of Leaves	1,65ns	1,98 ns	1,81 ns	1,47 ns	2,33*	2,048	2,763
Shoot Diameter	-	-	-	1,63 ns	2,38*	2,048	2,763

Information: ns (not noticeably different), *(significantly different)

Climate is a critical factor influencing plant growth and development. There is a strong correlation between climatic conditions, vegetative growth, and coffee productivity. Key climatic variables—such as temperature, light intensity, and humidity—play a vital role in supporting and optimizing the cultivation of coffee plants [14]. The microclimate in which plants grow has a direct impact on their growth and metabolic processes. Plants thrive in favorable climatic conditions, whereas unfavorable climate factors can induce stress and hinder growth.

Table 2 Average Results of Light Intensity, Temperature and Humidity Measurements

Parameter	Month				
	1	2	3	4	5
Light Intensity (%)	-	-	-	-	31,40
Temperature (°C)	27,88	28,01	25,83	26,54	26,33
Humidity (%)	76,25	74,88	78,63	80,13	81,75

Robusta coffee plants can photosynthesize well if they receive less than 60% sunlight. If the light intensity is too high or too low, photosynthesis will not be optimal[15]. So, sufficient light intensity will make the photosynthesis process good and will make the

shoots grow more optimally. During the observation, the average light intensity obtained in the fifth month after clipping obtained 31.40%.

Temperature is one of the most critical climatic factors influencing the growth and development of Robusta coffee plants. Robusta coffee thrives within an optimal temperature range of 22–28°C. When temperatures fall outside this range, either too high or too low, the rate of photosynthesis decreases significantly, adversely affecting plant growth [16]. The average temperature recorded during the observations varied across the five months. In the first month, the average temperature was 27.88°C; in the second month, it was 28.01°C; in the third month, it dropped to 25.83°C; in the fourth month, it was 26.54°C; and in the fifth month, it was 26.33°C.

Humidity plays a crucial role in regulating the water content of the soil, and plants are capable of maintaining their water balance even under low humidity conditions. When the soil can supply sufficient water to the plants, it positively impacts their growth. However, if soil moisture is lost faster than it can be replenished by evaporation, plants will begin to wilt and, ultimately, die. The optimal humidity range for growing Robusta coffee is between 70 and 75% [16]. The average humidity recorded during the observations varied across the five months. In the first month, the average humidity was 76.25%; in the second month, it was 74.88%; in the third month, it increased to 78.63%; in the fourth month, it was 80.13%; and in the fifth month, it rose to 81.75%.

3.1. Shoot Length

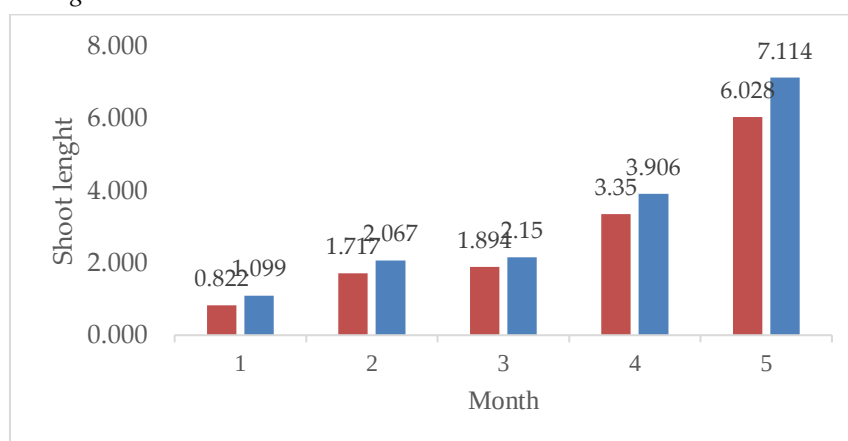


Figure 1. The average shoot length, red: average length of shoots left with one node, blue: average length shoots left with two nodes

Shoot length is an important parameter for evaluating the effects of different pruning treatments. Shoot length was measured one month after pruning, specifically for shoots that grew from the leaf axils of branches pruned according to the treatment procedure. The growth of shoot length is influenced by factors such as light intensity, temperature, and humidity in the coffee field.

Based on the independent T-test analysis presented in Table 1, there is no significant differences were observed in the shoot length (cm) parameter up to five months after pruning in both treatments. This lack of difference is likely due to the fact that the branches, whether pruned to leave one node or two nodes, were exposed to similar environmental conditions, including temperature, light intensity, and humidity (Table 2). As a result, the growth of the shoots did not show any substantial variation.

Figure 1, illustrates the growth pattern of shoot length. It shows that shoots with two nodes left grew faster than those with one node left. This can be attributed to the relatively dense shade in the BP308 Robusta coffee plant garden at the Jember State Polytechnic. The shorter branches that were left with one node were more shaded by the longer branches above, restricting light penetration. In contrast, branches left with two nodes had better

access to light, as their length was sufficient to avoid being overshadowed by the branches above. According to [16].

Light is an important factor related to the growth of coffee plants. The light intensity with 75% sunlight can be said to be the optimum light intensity. According to [17], Physiologically, light has both direct and indirect effects on plants. Directly, light influences photosynthesis, while indirectly, it affects plant growth and development through various metabolic reactions. Intense sunlight can suppress photosynthesis, leading to a reduced net assimilation rate and suboptimal plant growth. Conversely, insufficient sunlight can hinder the efficiency of photosynthesis, slowing down shoot elongation and limiting growth.

3.2. Number of Leaves

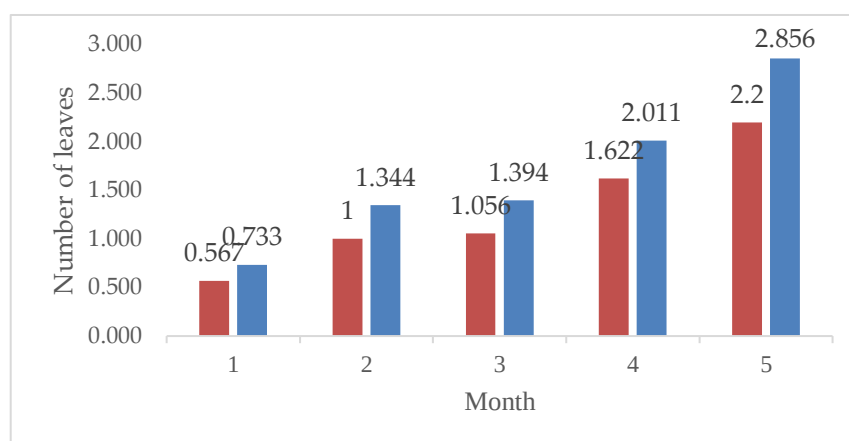


Figure 2. The number of leaves red: average length of shoots left with one node, blue: average length shoots left with two nodes

Leaves are an organ in plants that is a place to synthesize food according to needs and as a food reserve. Leaves contain chlorophyll which plays a role in photosynthesis. The more leaves there are, the more places there are for photosynthesis and the more produce there will be [18]. Coffee plant leaves grow in pairs, growing on branch nodes.

Based on the results of the analysis using the t test in Table 1, the parameter number of pairs of leaves (pairs) shows that the results are not significantly different from the first observation to the fourth observation. However, the fifth observation showed significantly different results as shown in Figure 2, coffee plants that had one node left in the fifth observation that were approximately 4-5 months old showed an average of 2.20 pairs, while at the same age coffee plants that had two nodes left showed a higher average of 2.86 pairs. This is because the branches that have two nodes left have a greater number of leaves. The more leaves, the more active the photosynthesis process will be.

Branches that retain two nodes tend to develop a greater number of leaves compared to those with only one node. Each node contains potential nodes where new leaves can emerge, and with more nodes preserved, there are more meristematic sites available for leaf development. This results in an increased leaf area, which is crucial for supporting the plant's overall growth and productivity. An increased number of leaves enhances the photosynthetic capacity of the plant. More leaves mean a larger surface area to capture light energy, facilitating a higher rate of photosynthesis. This, in turn, can lead to greater biomass accumulation and improved plant vigor. According to Taiz et al. (2015), leaf area is directly correlated with photosynthetic efficiency, as it determines the extent of light interception and gas exchange. Therefore, pruning practices that preserve more nodes may contribute to more active physiological processes and better vegetative growth outcomes.

Food reserves produced during photosynthesis are used in the respiration process as a substrate to produce energy, which is then used for plant growth and development, including shoot formation [19]. So, branches that have two nodes left can experience faster growth and increase in the number of pairs of leaves. Apart from these factors, it can also be caused by internal and environmental factors. Internal factors mean factors that can influence the photosynthesis of green plants themselves, such as leaf age and chlorophyll content. When plants experience leaf growth, the chlorophyll in the leaves also gradually increases.

Increasing the amount of chlorophyll increases the plant's ability to capture sunlight, thus further speeding up the rate of photosynthesis. Older leaves generally have much less chlorophyll, so their ability to capture light and carry out photosynthesis is also reduced. On the other hand, the photosynthesis process requires environmental factors, namely sunlight. Sunlight acts as an energy source that converts water and carbon dioxide into glucose. The absorption of sunlight by plants depends on the intensity of sunlight, the wavelength of light, and the duration of exposure [20].

Robusta coffee plants can photosynthesize well if they receive less than 60% sunlight. If the light intensity is too high or too low, photosynthesis will not be optimal [15]. So, sufficient light intensity will make the photosynthesis process good and will make the shoots grow more optimally which automatically also affects the growth of the number of pairs of leaves. According to [21], photosynthesis in leaves produces photosynthesis, which will be transmitted to the shoots, stems and roots. Meanwhile, photosynthesis that occurs in young leaves will not be passed on to other parts. Thus, the number of pairs of leaves is influenced by the photosynthesis process in plants, and also the number of pairs of leaves will influence the results of photosynthesis and water content in plants. The more leaves the results of photosynthesis will be optimal and the water content in the plant will also increase and vice versa.

3.3. Shoot Diameter

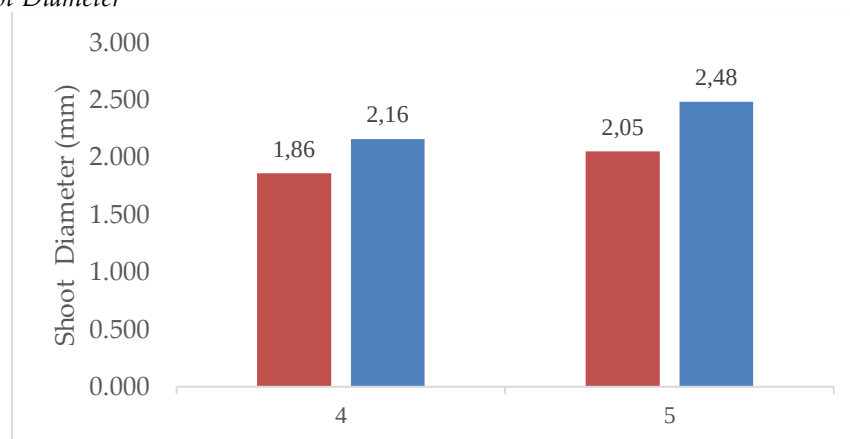


Figure 3. Shoot diameter, red: average length of shoots left with one node, blue: average length shoots left with two nodes

Measurements of shoot diameter parameters were only carried out at the end of the observation because there were concerns that it could injure newly growing shoots if measured from the start of the observation and to minimize failures in the research. Based on the results of the analysis, there is no significant difference between the first and fourth observations of shoot diameter parameters (mm). However, in the fifth observation, shoot diameter showed significantly different results. T-test results for shoot diameter parameters can be seen in Table 1. This can happen because the fifth observation fell in November, which started to rain more frequently compared to the previous month, although rainfall was still relatively low due to the start of the long dry season. The following is rainfall data in Jember Regency.

Table 3. Rainfall in Jember RegencySource: *World Weather Online*, 2023

Source: World Weather Online, 2023																
Date	Month															
	Oct 2023									Nov 2023						
	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	Amount
Rainfall (mm)	0,2	0	0,1	0	0	1,6	7	1,6	0,1	0,1	3	2,1	1,2	1,3	0,5	18,8

As shown in Table 4.3, the rainfall recorded in Jember Regency during the fifth month after the treatment was relatively low, yet it had a significant impact on the growth of the coffee shoot diameter. This was likely due to the rainfall following an extended dry season, which provided much-needed moisture and improved plant growth compared to the previous month, when the coffee plants were still under the stress of prolonged drought. Additionally, the presence of shade plants helped regulate the environment by blocking some sunlight, which prevented direct exposure to the sun and helped maintain optimal humidity levels around the coffee plants. According to [17], humidity functions to regulate the loss of water or water vapor through evapotranspiration. High humidity reduces the risk of water loss, while low humidity increases the risk of water loss.

Growth is a process in plant life that causes changes in plant size. Growth at the tip of the plant will tend to result in an increase in length (height) while lateral growth will result in lateral growth (diameter) [22]. The genetic characteristics of the diameter of new shoots on branches of coffee plants that are at least 5 months old are ≥ 8 mm [23]. Based on Figure 3, the average diameter of shoots on coffee plant branches with one node and two nodes remaining has an average size at the last observation or 4-5 months after pruning, namely 2.05 and 2.48 mm. These results are below the standard size of coffee plant shoot diameter. This is due to the long dry season which causes high environmental temperatures (Table 2), so that coffee plants experience slower growth. Supported by the opinion of [17], higher temperatures can cause flower abort and fruit formation to be temporarily reduced, growth becomes slow, stunted and uneconomical. Thus, high environmental temperatures make the shoot diameter smaller than the standard genetic trait of the shoot diameter itself.

4. Conclusions

There are significant differences were found in the number of leaf pairs and shoot diameter parameters. Based on average calculations, branches with two nodes showed a 22,96% higher average the number of leaves and a 17,39% higher average shoot diameter compared to one node.

5. Patents

This section is not mandatory but may be added if there are patents resulting from the work reported in this manuscript.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used “Conceptualization, D.H. and U.S.; methodology, D.H.; software, A.D.R.; validation, D.H., D.G.C and G.F.D.; formal analysis, A.D.R.; investigation, D.H.; resources, A.D.R.; data curation, XX.; writing—original draft preparation, D.H.; writing—review and editing, G.F.D.; visualization, D.G.C; supervision, D.H.; project administration, U.S.; All authors have read and agreed to the published version of the manuscript.”

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Informed Consent Statement: “Informed consent was obtained from all subjects involved in the study.”

“Written informed consent has been obtained from the patient(s) to publish this paper”

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Conflicts of Interest: The authors declare no conflict of interest.

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