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Optimization of Arabica Coffee (*Coffea arabica* L.) Shoot Cutting Growth Using Plastic Bottle Covers and Goat Urine Treatments

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Abstract

Arabica coffee (*Coffea arabica* L.) is a high-value commodity, yet its productivity in Indonesia remains low due to suboptimal cultivation techniques. One of the main constraints is the limited availability of quality seedlings, which is influenced by propagation methods. Vegetative propagation through shoot cuttings is widely used, but often constrained by low survival and root formation rates. The application of plastic bottle covers and goat urine has the potential to improve propagation success by creating a favorable microclimate and supplying growth regulators and essential nutrients. This study examined the effects of plastic bottle cover types and goat urine concentrations on the growth of C. arabica shoot cuttings. The experiment was arranged in a 3×3 factorial Completely Randomized Design (CRD), with two factors: plastic bottle cover types (no cover, open-cap cover, and closed cover) and goat urine concentrations (0, 100, and 180 mL/L). Observed parameters included shoot length, shoot number, leaf length, leaf number, root length, root number, and root diameter. Data were analyzed using analysis of variance (ANOVA) followed by Tukey's Honestly Significant Difference (HSD) test at a 5% significance level. The results showed a significant interaction between cover type and goat urine concentration. Combining a closed cover with 100 mL/L goat urine produced the highest shoot growth, cutting survival rate, and rooting percentage, while optimal root development was obtained with the closed cover and 180 mL/L goat urine. The most effective treatment was the closed cover combined with 100 mL/L goat urine.

Keywords: Vegetative; rooting; microclimate; organic fertilizer; propagation.

INTRODUCTION

Arabica coffee (*Coffea arabica* L.) has high economic value and is one of Indonesia's leading plantation commodities. However, national coffee production has not yet reached its full potential, partly due to the limited availability of high-quality planting material. Generative propagation using seeds often fails to maintain the desirable traits of elite mother plants and requires a long period before reaching productivity (Ginanjar et al., 2020). Vegetative propagation through shoot cuttings provides a more efficient alternative, producing uniform seedlings that inherit superior parental traits and reach productivity more quickly (Mbwambo et al., 2024). Despite these advantages, the success rate of shoot cutting propagation is often low due to physiological constraints, such as limited root initiation and high mortality during early growth stages (Widodo et al., 2016).

One key factor influencing rooting success is the regulation of the microenvironment, particularly air humidity. The use of covers, such as humidity domes, helps maintain high moisture levels around the cuttings, reduce transpiration, and preserve cell turgor necessary for active metabolism and root initiation (Gunawan et al., 2016). Repurposing used plastic bottles as protective covers represents an environmentally friendly and easily applicable solution.

In addition to environmental control, applying natural plant growth regulators can play a significant role in stimulating root and shoot development. Goat urine has been reported to contain growth-promoting hormones, including auxins and gibberellins, as well as essential nutrients that support cell division and elongation (Lestari et al., 2024).

Although the positive effects of microenvironmental regulation and natural growth stimulants have been independently documented, there is limited research on their combined use for the vegetative propagation of *C. arabica*. Moreover, existing studies have not fully addressed how this combination can overcome the limitations of current propagation practices. Therefore, the present study aimed to evaluate the interactive effects of plastic-bottle covers and goat urine application on the vegetative growth of Arabica coffee shoot cuttings, with

the ultimate goal of developing a more effective and practical propagation technique.

MATERIALS AND METHODS

Study area

The experiment was conducted in Doro Village, Doro Subdistrict, Pekalongan Regency, Central Java, at coordinates -7.031239° S and 109.690022° E. The site is situated at an altitude of approximately 650 m above sea level. Microclimatic conditions under the paranet during the study period showed an average daily temperature of 23–28 °C and relative humidity of 70–85%, based on direct measurements using a digital thermometer-hygrometer. The study was conducted during the rainy season, from October 2024 to February 2025.

Tools and Materials

The tools used included 1,500 mL plastic bottles, a plastic tarp for collecting goat urine, 75% shade netting for protection, and glass jars with lids for fermentation.

The materials included shoot cuttings from three-year-old *C. Arabica* plants, fresh goat urine, molasses, EM4. Shoot cuttings were taken between the second and fifth nodes, each measuring approximately 17 cm in length and 0.4 cm in diameter, containing three nodes and two pairs of leaves trimmed to half size to reduce transpiration (Figure 1). Goat urine was collected directly from a local farm, filtered, and temporarily stored in closed containers before fermentation.

Figure 1. Shoot cuttings of Arabica coffee (Safinah, 2025).

Procedures

Preparation of Planting Substrate

The substrate consisted of soil and compost mixed in a 2:1 ratio. The 1,500 mL plastic bottles were cut into two parts (upper and lower). The lower section was filled with the substrate to full capacity, while the upper section was repurposed as a cover.

Fermentation of Goat Urine

Goat urine and molasses were mixed in a 2:1 ratio, followed by the addition of 15 mL EM4 per liter of mixture. The solution was placed in glass jars, sealed tightly, and fermented for 14 days at approximately 27 °C under semi-anaerobic conditions. The mixture was stirred every two days before resealing.

Treatments

The plastic bottle cover treatment was carried out immediately after soaking the cuttings in goat urine. And ended 16 weeks after planting (MST). The first treatment used a variety of plastic bottle covers, namely no covers (S0), covers with the bottle cap opened (S1), and tightly closed covers (S2), as shown in Figure 2. The second treatment was immersion of Arabica coffee shoot cuttings in goat urine solution for 9 hours with three concentrations, namely 0 mL/L (P0), 100 mL/L (P1), and 180 mL/L (P2).

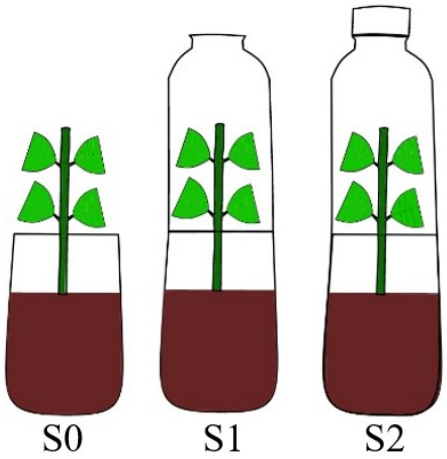

Figure 2. Treatment of plastic bottle cover variation. Description: No cover (S1), open cover (S2), and closed cover (S3) (Safinah, 2025).

Planting of Cuttings

The shoot cuttings were planted vertically to a depth of approximately 5 cm in the substrate-filled bottles. The bottles were arranged based on the experimental design within a 1.5 m × 1.0 m plot protected with 75% shade netting.

Experimental Design

A factorial completely randomized design (CRD) was used, with two factors. The first factor was goat urine concentration (P): P0 = 0 mL/L, P1 = 100 mL/L, P2 = 180 mL/L. The second factor was bottle cover type (S): S0 = no cover, S1 = open cover, S2 = closed cover (Table 1).

Table 1. Factorial completely randomized design (CRD) of plastic bottle cover variation and goat urine.

Type of plastic bottle covers	Goat urine concentration (mL/L)		
	0 (P0)	100 (P1)	180 (P2)
No cover (S0)	S0P0	S0P1	S0P2
Open cover (S1)	S1P0	S1P1	S1P2
Closed cover (S2)	S2P0	S2P1	S2P2

Observed Parameters

The success of Arabica coffee shoot cutting propagation was evaluated through:

Shoot and leaf growth: number of shoots (count), number of leaves (count), shoot length (cm), and leaf length (cm).

Root growth: percentage of rooted cuttings (%), number of roots (count), root length (cm), and root diameter (mm). The formula for calculating the percentage of live cuttings and rooted cuttings is as follows:

1. Percentage of live cuttings (%)
   Percentage of live cuttings (%) = $\frac{number\ of\ live\ cuttings}{number\ of\ replicates} \times 100\ \%$
2. Persentase stek berakar (%)
   Percentage of rooted cuttings (%) = $\frac{number\ of\ rooted\ cuttings}{number\ of\ replicates} \times 100\ \%$

Data analysis

Data were analyzed using analysis of variance (ANOVA) followed by Tukey's Honestly Significant Difference (HSD) test was applied at the 5% significance level. All analyses were conducted using Microsoft Excel software.

RESULTS AND DISCUSSION

Effect of Plastic Bottle Cover and Goat Urine on Shoot and Leaf Growth of Arabica Coffee Shoot Cuttings.

The shoot and leaf growth of Arabica coffee shoot cuttings was evaluated based on the number of leaves, leaf length, number of shoots, and shoot length for 16 weeks after planting (MST) (Table 2).

Table 2. Shoot length (cm), number of shoots, leaf length (cm), and number of leaves of Arabica coffee shoot cuttings treated with plastic bottle and goat urine at 16 weeks after planting.

Parameters	Type of plastic bottle covers	Goat urine concentration (mL/L)		
		P0	P1	P2
Shoot length (cm)	S0	0,00 [d]	0,00 [d]	0,00 [d]
	S1	1,17 [c]	0,86 [c]	1,20 [b]
	S2	1,18 [b]	**1,73 [a]**	0,80 [c]
Number of shoots	S0	0,00 [c]	0,00 [c]	0,00 [c]
	S1	1,75 [b]	2,00 [b]	2,00 [b]
	S2	2,25 [b]	**3,75 [a]**	2,00 [b]
Leaf length (cm),	S0	0,00 [d]	0,00 [d]	0,00 [d]
	S1	2,37 [c]	2,22 [c]	3,02 [b]
	S2	2,30 [c]	**4,03 [a]**	2,13 [c]
Number of leaves	S0	0,00 [c]	0,00 [c]	0,00 [c]
	S1	5,00 [b]	5,50 [b]	4,75 [b]
	S2	**7,00 [a]**	**7,75 [a]**	6,00 [b]

Note. Treatment without cover (S0), cover opened (S1), cover closed (S2). Concentration of goat urine 0 mL/L (P0), 100 mL/L (P1), 180 mL/L (P2). Numbers followed by the same letter in the same parameter indicate no significant difference based on the HSD test at the 5% significance level.

ANOVA results showed an interaction between plastic bottle covers and goat urine on shoot length, number of shoots, leaf length, and number of leaves. The plastic bottle cover treatment had a significant effect on all parameters, while goat urine affected the number of shoots and leaf length. Cuttings without cover showed no growth of shoots and leaves in all goat urine treatments. In the open cover treatment with a goat urine concentration of 180 mL/L, there was an increase in shoot length and leaf length. The closed cover treatment with 100 mL/L goat urine increased shoot length, number of shoots, leaf length, and number of leaves. In contrast, with goat urine concentration of 180 mL/L, there was a decrease in all canopy growth parameters (Table 2).

Effect of Plastic Bottle Cover and Goat Urine on Root Growth of Arabica Coffee Shoot Cuttings

Root growth was evaluated based on the percentage of rooted cuttings, number of roots, root length, and root diameter which can be seen in (Table 3).

Table 3. Number of roots, length of roots (cm), and diameter of roots (mm) in Arabica coffee shoot cuttings treated with plastic bottle and goat urine at 16 weeks after planting.

Parameters	Type of plastic bottle covers	Goat urine concentration (mL/L)		
		P0	P1	P2
Number of roots	S0	0,00 [d]	0,00 [d]	0,00 [d]
	S1	1,50 [c]	1,35 [c]	2,25 [b]
	S2	1,50 [c]	1,13 [c]	**3,75 [a]**
Length roots (cm)	S0	0,00 [d]	0,00 [d]	0,00 [d]
	S1	3,68 [c]	4,17 [c]	4,85 [c]
	S2	4,17 [c]	5,20 [b]	**6,60 [a]**
diameter of roots (mm)	S0	0,00 [d]	0,00 [d]	0,00 [d]
	S1	1,50 [c]	1,40 [c]	1,38 [c]
	S2	1,63 [b]	**1,80 [a]**	**1,78 [a]**

Note. Treatment without cover (S0), cover opened (S1), cover closed (S2). Concentration of goat urine 0 mL/L (P0), 100 mL/L (P1), 180 mL/L (P2). Numbers followed by the same letter in the same parameter indicate no significant difference based on the HSD test at the 5% significance level.

ANOVA results showed an interaction between the plastic bottle and goat urine treatment on the number of roots, root length and root diameter in Arabica coffee shoot cuttings. The plastic bottle cover treatment significantly affected all parameters, while goat urine had no effect on root diameter. The uncovered treatment at all concentrations of goat urine showed no root growth. In the open cover treatment with goat urine concentration of 180 mL/L, the number of roots of Arabica coffee cuttings increased, but root length and diameter were not significantly different in all concentrations of goat urine. In the closed cover treatment, the highest number of roots and root length were shown in the 180 mL/L goat urine concentration treatment, while the root diameter parameter was not significantly different between goat

urine concentrations of 100 mL/L and 180 mL/L (Table 3).

Figure 4. Rooting of Arabica coffee shoot cuttings 16 weeks after planting. Description. Root length of Arabica coffee shoot cuttings without cover with goat urine 0 mL/L (a), without cover with goat urine 100 mL/L (b), without cover with goat urine 180 mL/L (c), open cover with goat urine 0 mL/L (d), open cover with goat urine 100 mL/L (e), open cover with goat urine 180 mL/L (f), closed cover with goat urine 0 mL/L (g), closed cover with goat urine 100 mL/L (h), closed cover with goat urine 180 mL/L (i).

Table 4.2 and Figure 4.2 show the rooting of Arabica coffee cuttings obtained from a combination of plastic bottle cover treatment and goat urine concentration. In Figure 4.2, the best root length and number occurred in the closed cover treatment with a goat urine concentration of 180 mL/L.

Live Percentage of Arabica Coffee Shoot Cuttings.

The percentage of live cuttings was calculated from the number of still alive cuttings until the end of observation, divided by the number of replicates planted. The percentage of rooted cuttings was obtained from the number of cuttings that formed roots divided by the number of replicates. Cuttings are declared alive when the color is still fresh green, not withered or rotting (Nengsih & Wahyu, 2021). Data on the percentage of live cuttings can be seen in Table 4.

Table 4. Percentage of live Arabica coffee shoot cuttings treated with plastic bottle and goat urine at 16 weeks after planting.

Parameters	Type of plastic bottle covers	Goat urine concentration (mL/L)		
		P0	**P1**	**P2**
Percentage of live cuttings (%)	S0	0	0	0
	S1	33	50	66
	S2	33	**100**	33
Percentage of rooted cuttings (%)	S0	0	0	0
	S1	33	50	**66**
	S2	33	**66**	33

Note. Treatment without cover (S0), cover opened (S1), cover closed (S2). Concentration of goat urine 0 mL/L (P0), 100 mL/L (P1), 180 mL/L (P2).

In the treatment without a cover, the percentage of live and rooted cuttings was 0% in all goat urine concentrations (0, 100, and 180 mL/L). The use of a closed cover on goat urine with a concentration of 100 mL/L showed the highest results with 100% live cuttings and 66% rooted cuttings (Table 4). Despite the 100% survival rate, not all cuttings were fully rooted. Based on observations, two of the cuttings only formed callus (Figure 5). This indicates that although the cuttings had not formed roots, the presence of active callus and the high humidity environment allowed the cuttings to survive until the end of the observation.

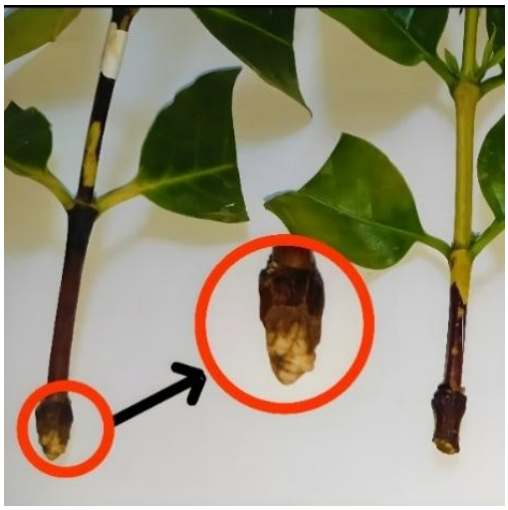

Figure 5. Arabica coffee shoot cuttings that had just formed callus in the closed cover treatment with goat urine concentration of 100 mL/L at 16 weeks after planting (circle mark).

Discussion

The treatment without a cover caused a significant decrease in growth and the death of cuttings. This condition is thought to be caused by the low air humidity in an uncovered environment, which increases the transpiration rate and leads to water loss exceeding the absorption capacity of the cuttings. Sahlim (2023) stated that the absence of a cover reduces microclimate humidity, increases water evaporation, and causes failure in the growth of patchouli (Pogostemon cablin Benth.) shoot cuttings. High temperature and humidity fluctuations in an open environment also do not support the rooting process. This is reinforced by (Druege et al., 2019), who stated that excess transpiration lowers cell turgor pressure, thus inhibiting cell division and differentiation required in adventitious root formation. Additional support comes from the study of (Shen et al., 2025) which showed that at low humidity, mulberry cuttings failed to form callus and roots, and experienced high mortality rates.

In the cover treatment with the bottle cap removed, the humidity inside the cover tends to be lower than in the closed cover, which creates moderate conditions for growth. Braun & Wyse (2019) state that the relative humidity in ventilated covers is around 59%, while closed covers reach 90%. This moderate humidity is

proven to support the optimal physiological function of stomata. Fanourakis et al. (2020) explained that at a humidity of around 59%, the mechanism of stomatal opening and closing mediated by abscisic acid (ABA) can function properly, so that transpiration and absorption of water and nutrients take place efficiently. This condition was seen in the 180 mL/L goat urine treatment in open covers, which showed an increase in shoot and leaf length. This indicates that the increased concentration of nutrients from goat urine at moderate humidity can be optimally utilized by plants.

The effectiveness of goat urine in increasing growth is also closely related to the content of active compounds in it. (Lestari et al., 2024) mentioned that goat urine contains growth hormones such as auxin, cytokinin, and gibberellin, as well as NPK macro nutrients. The content supports cell elongation, cell division, and the growth of plant vegetative organs. Auxin is known to play a role in cell elongation and root formation (Sembiring et al., 2023). Cytokinin stimulates cell division and shoot growth (Di Bonaventura et al., 2024), while gibberellin spurs stem growth and other vegetative parts (Ben-Targem et al., 2021). These results are in line with the research of (Juliyansyah et al., 2024) which showed that the application of NPK from goat urine at 5% oncx areca nut plants increased plant height, number of leaves, and leaf area. However, the difference in effectiveness between the shoot and leaf and roots at certain concentrations indicates that the sensitivity of plant tissues to hormones also plays a role. According to Jang et al. (2024) and Taiz et al. (2015) roots have a higher sensitivity to auxin, while shoots are more responsive to cytokinin, which explains the variation in response in growth parameters between the upper and lower parts of the plant.

The results of this study also showed that high humidity in closed covers negatively affected growth, especially when combined with a high concentration of goat urine (180 mL/L). At relative humidity ≥85%, Fanourakis et al. (2020) noted a decrease in ABA levels in leaves, which caused stomata to become less responsive to closing signals. As a result, transpiration remains high, even under moisture-saturated conditions. (Fanourakis et al., 2013) also stated that increased residual stomatal conductance (residual gs) at high humidity leads to increased water loss through the cuticle, which exacerbates transpiration. This condition accelerates the absorption of solutes such as ammonia from goat urine, which in excess amounts is toxic to plant tissues.

Ammonia is a compound formed under anaerobic conditions due to low oxygen levels in the growing medium (Bittsánszky et al., 2015). Excessive absorption of ammonia increases osmotic pressure and cell permeability, so ammonia easily enters the tissue and accumulates in high concentrations. In high amounts, ammonia is corrosive and causes cell death, which can be seen from the symptoms of necrosis in the stem cuttings in the form of blackish discoloration. Priyambodo et al. (2019) explained that although the goat urine fermentation process can reduce ammonia levels, the compound cannot be eliminated. This statement is in line with the findings of Li (2024), who stated that ammonia is toxic to plants, causing cell damage and triggering tissue death. In addition, Shen et al. (2025) mentioned that high humidity also creates a favorable environment for the growth of pathogens such as fungi and bacteria, thus exacerbating plant tissue damage due to secondary infections.

Stressful conditions due to ammonia toxicity and pathogen infection cause plants to divert metabolic energy from growth to the defense system. Feng et al. (2022) explain that under biotic and abiotic stress conditions, plants increase the production of antioxidant compounds, strengthen cell walls, and activate stress hormone pathways such as ethylene or jasmonate. These responses deplete energy resources that would otherwise be used for adventitious root formation. As a result, root formation is inhibited or fails, as seen in treatments with high urine concentration and humidity.

Overall, the results of this study indicate that the combination of proper microclimate humidity and optimal nutrient concentration is key to the successful vegetative growth of arabica coffee cuttings. The closed cover treatment with 100 mL/L goat urine proved to be the most effective in improving growth parameters and the percentage of live cuttings. Conversely, the use of high concentrations of goat urine in high humidity can be a stressor that causes physiological damage and inhibits plant growth.

CONCLUSIONS

The combination of a closed cover with 100 mL/L goat urine produced the highest shoot growth, cutting survival rate, and rooting percentage. Meanwhile, optimal root development was observed with the closed cover and 180 mL/L goat urine. The most effective treatment overall was the closed cover combined with 100 mL/L goat urine.

Competing Interests: The authors declare that there are no competing interests.

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