# Maximizing cocoa (Theobroma cacao L.) seedling growth

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# Maximizing cocoa (*Theobroma cacao* L.) seedling growth through liquid coconut shell smoke in Ultisols soil

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## ABSTRACT

The crucial aspect of cocoa cultivation is ensuring the availability of seedlings with robust growth. Ultisols, a type of soil with potential for cocoa plant propagation, necessitate materials to enhance fertility when used as a growing medium. This includes the application of liquid smoke derived from coconut shells. To further study on this aspect this research aimed to determine the role of liquid coconut shell smoke on the growth of cocoa seedlings in Ultisols soil. The research was conducted in the laboratory and greenhouse of the Faculty of Agriculture, Panca Bhakti University, Pontianak, for 90 days from July to October 2023. The research used a complete randomized block design (CRBD) with four replications. The treatment concentrations of liquid coconut shell smoke (%) consisted of six levels: 0.00, 0.25, 0.50, 0.75, 1.00, and 1.25%. Each replication consisted of three cocoa plant seedling samples, resulting in a total of 72 plants for the entire research unit. The observed parameters included plant height increase (cm), the increase in the number of leaves (leaves), and the increase in stem diameter (mm). The research results found a very significant influence on all observed parameters. The treatment of liquid coconut shell smoke at a concentration of 0.75% yielded the highest results in terms of seedling height increase (29.09 cm), the number of leaves (14.08 leaves), and stem diameter (9.87 mm) compared to the control. This research finding shows that a concentration of 0.75% liquid coconut shell smoke can maximize the growth of cocoa seedlings in Ultisols soil through soil fertility improvement.

**Key words:** Cocoa, Coconut shell, liquid smoke, Ultisols soil

## INTRODUCTION

Cocoa (*Theobroma cacao* L.) was one of the important plantation crops in Indonesia, contributing to the national economy (Wijayati and Haqqi, 2022). There was an increasing demand for cocoa beans and their derivatives, growing up to three times faster than their production in the global economy, and it was predicted to increase by 20% in the coming decade (Suh and Molua, 2022). Therefore, strategies for increasing cocoa production were necessary, including the use of high-quality cocoa seedlings in cultivation techniques (Bahrun *et al.*, 2019). To obtain high-quality seedlings, the choice of planting medium was of utmost importance (Prameswari and Tata, 2004; Aysegul and Ibrahim, 2019). The use of fertile planting media would yield good seedlings and promote sustainable cocoa production Anthonio *et al.* (2018). In this context, the use of organic fertilizers in the planting medium would influence cocoa seedling growth (Tarigan *et al.*, 2018; Padjung *et al.*, 2019).

The primary focus in cocoa seedling propagation was the soil fertility level as the growing medium. The growing medium had to meet the physical and chemical property requirements suitable for seedling growth (Prameswari and Tata, 2004) because seedling growth was measured by the increase in dry weight influenced by the nutrient availability in the growing medium (Cruz Neto *et al.*, 2015). Thus, the growing medium played a crucial role in plantation crop development due to its impact on plant growth and quality (Prameswari and Tata, 2004).

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The use of Ultisols as a growing medium faced inherent soil constraints. Plant growth was inhibited on this type of soil due to its high acidity, nutrient deficiency, unstable aggregates, and low organic matter (Pawar *et al.*, 2018; Kola *et al.*, 2018; Selvia *et al.*, 2019). Ultisols were characterized as less suitable for plant growth (Taisa *et al.*, 2019), necessitating soil amendments for improvement. One such effort was the application of liquid smoke. Studies on post-forest fire phenomena showed that smoke infiltration into the soil could affect the germination of various plant seeds after a forest fire. For example, seeds that lay dormant for years in the soil could be stimulated to germinate after exposure to smoke (Noel *et al.*, 2022).

Liquid smoke was the condensation or distillation product of direct or indirect combustion vapor from materials containing lignin, cellulose, hemicellulose, and other carbon compounds. Various chemical constituents in liquid smoke, such as alcohols, aldehydes, ketones, and organic acids like furfural and formaldehyde, could be used as preservatives (Winarni *et al.*, 2021). Additionally, liquid smoke contained acetic acid that could stimulate plant growth (Sriharti *et al.*, 2020). In this context, the use of liquid smoke had an impact on plant physiology (Gupta *et al.*, 2019; Noel *et al.*, 2022), germination, and seedling growth (Elsadek and Yousef, 2019).

Liquid smoke applied to the soil had the potential to produce healthy and robust plant seedlings because it could improve the soil's physical and chemical properties (Yuniwati and Lestari, 2020). Moreover, it could suppress diseases and enhance plant resistance (Aisyah *et al.*, 2018) as it contained phenol, quinol, and pyrogallol, which were beneficial as antioxidants, antiseptics, and antibacterial agents (Winarni *et al.*, 2021). Various raw materials could be used for liquid smoke production, including coconut husks, which contained cellulose, hemicellulose, and lignin (Aisyah *et al.*, 2018). Recognizing this potential, liquid smoke could become an environmentally friendly choice in organic agriculture development (Diptaningsari *et al.*, 2022).

Liquid smoke had an influence on seed germination and plant seedling growth. In this regard, Bhardwaj (2012) found that low concentrations of liquid smoke (0.1-0.2%) could enhance papaya seed germination and produce healthy seedling growth. The best seed germination and seedling vigor were also achieved in *Sceletium tortuosum* plants with a 0.1% concentration of liquid smoke treatment (Sreekissoon *et al.*, 2021). Each type of liquid smoke made from specific materials had its unique compatibility with seed germination and plant seedling growth (Elsadek and Yousef, 2019), so finding the right concentration of liquid smoke was necessary.

Research on the use of liquid smoke had been conducted on various plants. However, the use of coconut shell liquid smoke in cocoa seedling propagation had not been explored yet. The application of specific concentrations of coconut shell liquid smoke could potentially support maximum cocoa seedling growth in Ultisols soil. Therefore, this study aimed to determine the role of coconut shell liquid smoke in the growth of cocoa seedlings in Ultisols soil.

## MATERIALS AND METHODS

### Place and Time

The research was conducted in the laboratory and greenhouse of the Faculty of Agriculture, Panca Bhakti University, Pontianak, West Kalimantan Province, Indonesia, from July to October 2023. The research site was located at an elevation of one meter above sea level, with an average air temperature of 27.6°C and humidity of 82.8%. The research site was situated at a latitude of 2°05' N to 3°05' S and a longitude of 108°30' to 144°10' E.

### Research Design and Data Analysis

The research employed a Complete Randomized Block Design (CRBD) with four replications. The treatment concentrations of liquid smoke (%) consisted of six levels: 0.00, 0.25, 0.50, 0.75, 1.00, and 1.25%. Each replication included three samples of cocoa plant seedlings, resulting in a total of 72 plants in the entire research unit.

### Research Implementation

The Ultisols soil was collected in

composite form from farmers' fields in Peniraman Village, Sungai Pinyuh District, Mempawah Regency, West Kalimantan Province, Indonesia. The soil was cleaned of debris and sieved with a 1 x 1 cm mesh. Subsequently, 5 kg of soil was placed in polybags measuring 30 × 20 cm, totalling 72 polybags. For soil chemical property research, 100 g of soil was taken, and the pH level was observed in a soil solution with a 1:2.5 ratio (with deionized water), using a pH meter (Jenway 3305). The Walkley and Black wet oxidation method was used to determine the organic C content. Total N content was measured using the Kjeldahl method. Cation exchange capacity (CEC) was extracted with 1 M $NH_4OAc$ (buffer at pH 7.0), and the concentration of basic cations was measured using AAS (Shimadzu), available P with Bray I.

Cocoa plant seedlings var. Criolo obtained from a licensed seedling grower was used in this study. Seedlings aged 3 months with uniform height were selected. Before transferring seedlings to the research soil medium in polybags, initial measurements of seedling height, leaf count, and stem diameter were taken.

Liquid smoke production used a pyrolysis reactor with coconut shell as the raw material. The produced smoke was then condensed to obtain liquid smoke. Subsequently, treatment concentrations were prepared by diluting liquid smoke into water based on volume ratios in a 1000 mL solution. The process is as follows: 1) 0.25% concentration, where 2.5 mL of liquid smoke is added to a 1000 mL measuring glass and topped up with 997.5 mL of water, 2) 0.50% concentration, where 5 mL of liquid smoke is added to a 1000 mL measuring glass and topped up with 995 mL of water, 3) 0.75% concentration, where 7.5 mL of liquid smoke is added to a 1000 mL measuring glass and topped up with 992.5 mL of water, 4) 1.00% concentration, where 10 mL of liquid smoke is added to a 1000 mL measuring glass and topped up with 990.0 mL of water, and 5) 1.25% concentration, where 12.5 mL of liquid smoke is added to a 1000 mL measuring glass and topped up with 987.5 mL of water.

Each concentration of liquid smoke was used as a treatment in the study. Treatment application involved watering each research unit, namely polybag soil medium, one week before planting, and also at 2 weeks and 4 weeks after cocoa plant seedling.

**Observed Parameters**

The observation of cocoa seedling growth increment was carried out by collecting data at 12 weeks after planting and subtracting the initial growth data. The parameters for growth increment are included.

The observation of cocoa plant seedling growth was conducted by subtracting the data at 12 weeks after planting from the initial growth data. The parameters for growth include Increase in Plant Height (cm): Measured from the base of the stem to the highest point, Increase in Leaf Count (leaves): Counted as the number of fully formed leaves, Stem Diameter (mm): Measured using callipers at the base of the stem, 5 cm above the soil surface. This method allows for the assessment of the growth development of cocoa seedlings by comparing their growth at 12 weeks after planting with the initial measurements.

To determine the influence of liquid smoke on cocoa seedling growth, analysis of variance (ANOVA) was conducted at a 5% significance level. If there was a significant effect from the treatment, a Least Significant Difference (LSD) test was performed at a 5% significance level ($\alpha$ = 0.05) to identify the differences between the means of the treatments.

## RESULTS AND DISCUSSION

### Chemical Properties of Soil

The analysis of Ultisol soil used as the growing medium for cocoa plant propagation indicates the presence of growth-limiting factors. This is evident from several chemical properties identified in the soil analysis, as outlined in Table 1.

The presence of limiting factors, namely acidic pH (4.25), moderate organic C content (1.56%), low total N (0.17%), low P2O (5.50 ppm), and low K (0.30 cmol (+) $kg^{-1}$), as shown in Table 1, can impede the growth of cocoa seedlings. Therefore, materials that can enhance cocoa seedling growth, such as the application of liquid smoke, are needed. In line

**Table 1.** Chemical properties of Ultisol as a growing medium for cocoa seedlings

| Analysis Parameter | Contents in the soil | Criteria |
|---|---|---|
| pH $H_2O$ | 4.52 | Acidic |
| pH KCl | 4.21 | - |
| C-Organik (%) | 1.56 | Moderate |
| Total Nitrogen (%) | 0.17 | Low |
| P2O (ppm) | 5.50 | Low |
| Kalium (cmol (+) $Kg^{-1}$ | 0.30 | Low |
| Natrium (cmol (+) $Kg^{-1}$ | 0.13 | Low |
| Kalsium (cmol (+) $Kg^{-1}$ | 0.70 | Low |
| Magnesium (cmol (+) $Kg^{-1}$ | 0.19 | Very Low |
| KTK (cmol (+) $Kg^{-1}$ | 9.68 | Low |

Source: Laboratory analysis results (2023).

with this, Yuniwati and Lestari, 2020 found that liquid smoke can improve soil properties, thus supporting cocoa seedling growth. On the other hand, liquid smoke contains hormones that can enhance seedling growth (Elsadek and Yousef, 2019).

### Height of Cocoa Seedlings (cm)

Different concentrations of liquid smoke treatment had an impact on the height increment of cocoa seedlings. The results of the 5% LSD test in Table 1 showed that the treatment with 0.75% liquid smoke concentration yielded the highest result (29.09 cm) for the height increment of cocoa seedlings, but it was not significantly different from 0.25% and 0.50%. Furthermore, when the concentration of liquid smoke was increased to 1.25%, there was a decrease in height increment to 19.79 cm. In this regard, Fig. 1 indicates that the height increment of cocoa seedlings decreased as the concentration of liquid smoke applied increased.

**Table 2.** Results of the LSD test for the effect of liquid smoke application on the mean height increment of cocoa seedlings

| Liquid smoke concentration (%) | Mean seedling height (cm) |
|---|---|
| 0.00 | 17.54$^{a}$ |
| 0.25 | 23.79$^{abc}$ |
| 0.50 | 26.71$^{bc}$ |
| 0.75 | 29.09$^{c}$ |
| 1.00 | 22.17$^{abc}$ |
| 1.25 | 19.79$^{ab}$ |

Note: The mean values followed by the same letter indicate no significant difference based on the P=0.05 LSD test.

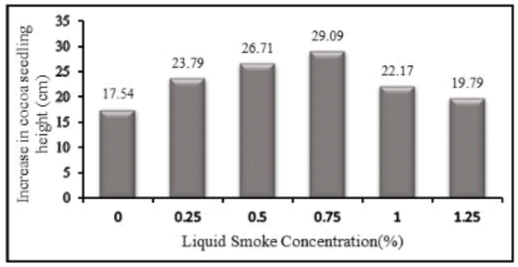


Fig. 1. Height (cm) increment of cocoa seedlings at various liquid smoke concentrations (%).

### Number of Cocoa Seedling Leaves

The application of various concentrations of liquid smoke had a significant effect on the leaf count increment of cocoa seedlings. The results of the 5% LSD test in Table 3 showed that the highest number of leaves was obtained in the treatment with 0.75% liquid smoke concentration (14.08 leaves), which was not significantly different from the 0.50% concentration (12.33 leaves). Increasing the concentration of liquid smoke led to a decrease in the number of leaves formed in cocoa seedlings, with the leaf count decreasing to 9.75 leaves at a higher liquid smoke concentration (1.25%), as indicated in Fig. 2.

**Table 3.** Results of the LSD test for the effect of liquid smoke application on the mean leaf count increment of cocoa seedlings (number of leaves)

| Liquid smoke Concentration (%) | Leaf Count Increment (number of leaves) |
|---|---|
| 0.00 | 9.67$^{a}$ |
| 0.25 | 11.67$^{ab}$ |
| 0.50 | 12.33$^{bc}$ |
| 0.75 | 14.08$^{c}$ |
| 1.00 | 10.33$^{ab}$ |
| 1.25 | 9.75$^{a}$ |

Note: The mean values followed by the same letter indicate no significant difference based on the P=0.05 LSD test.

### Stem Diameter of Cocoa Seedlings (mm)

The application of various liquid smoke concentrations showed a significant effect on the stem diameter increment of cocoa seedlings (mm). In Table 4, the results of the 5% LSD test on the mean stem diameter of cocoa seedlings showed the highest value in the treatment with 0.75% liquid smoke concentration, measuring 9.87 mm, which was

**Table 4.** Results of the LSD test for the effect of liquid smoke application on the mean stem diameter increment of cocoa seedlings (mm)

| Liquid Smoke concentration (%) | Stem Diameter Increment of Cocoa Seedlings (mm) |
|---|---|
| 0.00 | $5.00^{a}$ |
| 0.25 | $7.62^{ab}$ |
| 0.50 | $8.42^{b}$ |
| 0.75 | $9.87^{b}$ |
| 1.00 | $7.67^{ab}$ |
| 1.25 | $7.51^{ab}$ |

Note: The mean values followed by the same letter indicate no significant difference based on the P=0.05 LSD test.

significantly different from the control. However, it was not significantly different from the other concentration treatments. As shown in Fig. 3, there was a trend of decreasing stem diameter as the concentration was increased.

Ultisols is one of the most extensive soil orders, covering up to 45% of the land area in West Kalimantan, Indonesia. Recognizing its vast potential, it can be used for agricultural development, including as a planting medium for cocoa seedlings. This type of soil has already undergone advanced development characterized by the accumulation of clay in the B horizon, known as argillic (Soil Survey Staff, 2022). When used as a growing medium for cocoa seedlings, it is essential to address the growth-inhibiting characteristics of Ultisols. These inhibiting factors include having an acidic pH with high aluminum saturation, resulting in very low availability of P and other basic cations (Ca, Mg, K, and Na). One technology that can be used to improve the growing medium and enhance seedling growth is the use of liquid smoke (Bhardwaj, 2012).

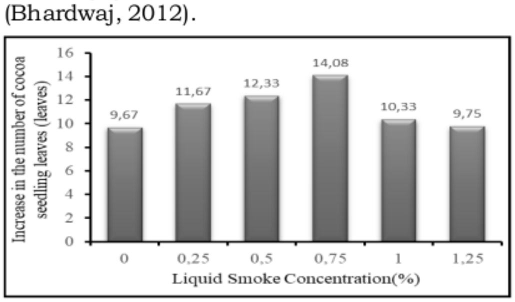


Fig. 2. Leaf count increment (number of leaves) at various liquid smoke (%) for cocoa seedlings.

In connection with this, the application of liquid smoke concentrations in West Kalimantan Ultisols showed an impact on the growth of cocoa seedlings, as observed in the variables of height increment (Table 1), leaf count increment (Table 2), and stem diameter increment (Table 3). This was because liquid smoke can improve the physical and chemical properties of the soil (Yuniwati and Lestari, 2020), stimulate germination and plant growth (Abedi *et al.*, 2018; Elsadek and Yousef, 2019; Sriharti *et al.*, 2020), and strengthen seedling vigor (Khatoon *et al.*, 2020). This was further emphasized by Winarni *et al.* (2021), highlighting the benefits of liquid smoke, such as promoting growth, strengthening root systems, enriching the soil, inhibiting the growth of plant pests and diseases, increasing the number of beneficial soil and plant microbes, and promoting healthy root systems.

Liquid smoke is effective in improving germination and seedling vigour, but it requires the regulation of its bio stimulants concerning the dosage provided (Sreekissoon *et al.*, 2021). The research results indicated that the highest values for height increment (Fig. 1), leaf count increment (Fig. 2), and stem diameter increment (Fig. 3) were achieved in the treatment with a 0.75% liquid smoke concentration. Among all the observed variables, the growth variables decreased when the liquid smoke concentration was increased to 1.00% and 1.25%. This phenomenon suggested that when using liquid smoke in the growing medium for cocoa seedlings, an optimum concentration should be considered. In this study, a 0.75% liquid smoke concentration supported the highest cocoa seedling growth.

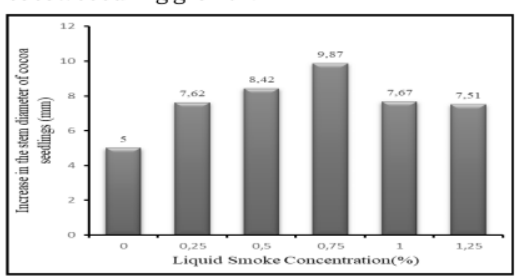


Fig. 3. Stem diameter increment of cocoa seedlings (mm) at various liquid smoke concentrations (%).

Many factors affect the germination and seedling growth processes, including light, temperature, humidity, and internal growth-regulating substances (Meng *et al.*, 2017;

Gupta *et al.*, 2019). Regarding the compounds contained in liquid smoke, there are thousands of compounds that are not yet known, and the positive impact on germination and seedling growth may depend on the plant species (Smith *et al.*, 2003). Liquid smoke plays a crucial role in hormone production during seedling growth (Elsadek and Yousef, 2019). Liquid smoke affects several biochemical processes, such as the activity of α-amylase and the accumulation of β-tubulin in dormant *Avena fatua* L. seeds (Cembrowska-Lech and Kepczynski, 2017). This reality suggests the physiological influence of liquid smoke on cocoa seedling growth. Thus, when liquid smoke is applied to Ultisols soil as a growing medium, it will affect cocoa seedling growth, as demonstrated in Tables 1, 2 and 3. However, further research is needed to examine the specific effects of liquid smoke on changes in the properties of Ultisols growing media.

## CONCLUSION

Based on the research findings, it was determined that liquid smoke significantly affects the increase in cocoa seedling growth in Ultisols soil. The treatment level of coconut shell liquid smoke at a concentration of 0.75% provided the best results in cocoa seedling growth, including height increment (29.09 cm), leaf count increment (14.08 leaves), and stem diameter increment (9.87 mm). However, cocoa seedling growth decreased when the concentration of liquid smoke exceeded 0.75%. Therefore, if coconut shell liquid smoke is used in cocoa seedling cultivation, it is advisable not to exceed a concentration of 0.75%.

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# Maximizing cocoa (Theobroma cacao L.) seedling growth

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