Vol. 10(2): 202-210, May 2022

DOI: https://doi.org/10.23960/jsl.v10i2.551

Jurnal Sylva Lestari

P-ISSN: 2339-0913
E-ISSN: 2549-5747

Journal homepage: https://sylvalestari.fp.unila.ac.id

Short-Communication

Cajuput (*Melaleuca cajuputi* (L.) Powell) Oil Yield and Cineole Analysis in Ex-Coal Mining Land with Monoculture and Agroforestry Patterns

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ARTICLE HISTORY:

Received: 10 October 2021
Peer review completed: 5 January 2022
Received in revised form: 12 January 2022
Accepted: 24 January 2022

KEYWORDS:

Agroforestry
Cineole
Essential oil
Ex-coal mining
Melaleuca cajuputi

ABSTRACT

Cajuput (*Melaleuca cajuputi*) has the potential to be developed with monoculture and agroforestry patterns in ex-coal mining land. This study aimed to analyze the oil yield and cineole content of cajuput planted with monoculture and agroforestry and patterns in ex-coal mining land. The research design used a split-split plot design with three factors: planting pattern, fertilizer dosage, and lemongrass (*Cymbopogon nardus*) plant spacing. The variables measured included the oil yield and cineole content of cajuput. This study was conducted in cajuput monoculture and agroforestry patterns with lemongrass G2 variety and Sitrona 2 Agribun variety, with various spacing. The study was conducted for six months, with one harvest of cajuput leaves in the sixth month. The results showed that lemongrass's planting pattern and plant spacing significantly affected cajuput oil yield. However, treatment of the dosage of fertilizer had no significant effect on cajuput oil yield. The treatment of lemongrass plant spacing only significantly affected cineole content, but planting patterns and fertilizer dosages had no significant effect. The cajuput agroforestry with the Sitrona 2 Agribun variety produced the highest oil yield (2.84%) and cineole content (50.70%), compared to the monoculture pattern and cajuput agroforestry with G2 variety. The lemongrass plant spacing of 0.5 m × 0.5 m produced the highest oil yield (2.73%) and cineole content (52.98%) compared to 1 m × 1 m plant spacing *Cymbopogon nardus*.

1. Introduction

Cajuput (*Melaleuca cajuputi*) is a multi-purpose tree species that produce non-timber forest products with high economic value (Alpian et al. 2013). This plant is one of the tree species that can produce essential oils for the cosmetic and pharmaceutical industries (Budiadi and Ishii 2010). Currently, the demand for cajuput oil continues to increase along with the emergence of the Covid-19 virus in Indonesia and the development of various industries that use cajuput oil (Rimbawanto et al. 2017). Cajuput oil has many properties, namely as an anti-viral, anti-microbial and respiratory treatment (Sudradjat 2020).

Cajuput can live in ex-mining reclamation land because it is a pioneer species, has high adaptability, grows fast, can improve physical, chemical, and biological properties (Buta et al. 2019; Mensah 2015; Pujawati 2009). It also has ecological and socio-economic benefits (Junaidi et al. 2015) and produces essential oils (Malau and Utomo 2017; Rusdiana et al. 2013; Subagio 2018). Ex-mining reclamation land currently has the opportunity to contribute to the development of cajuput agroforestry cultivation, especially in non-forest areas or *Area Penggunaan Lain* (APL) (Kodir et al. 2016). Agroforestry is a land-use system that combines agricultural and forestry crops has diversified production, ecological and social protection (Cardinael et al. 2017; Kaur et al. 2017; Suryani and Dariah 2012; Tarigan et al. 2019). Cajuput is highly adaptive developed with agroforestry systems (Priswantoro et al. 2021) to support food security programs (Suryanto et al. 2017).

The domestic demand for cajuput oil reaches 3,500 tons/ha (Rimbawanto et al. 2017) but can only be fulfilled at 400 tons/year (Muyassaroh 2016; Rimbawanto and Susanto 2004). The high demand for cajuput oil has created opportunities for monoculture and agroforestry cultivation on ex-mining reclamation land. The market price of cajuput oil is IDR 200,320/kg (MoEF 2019). Problems often faced in developing essential oils in Indonesia are low crop productivity (Sugiarto and Sulistyo 2010), varied oil quality, discontinuous supply of products and highly fluctuating prices (Kiyohara et al. 2012). In addition, post-harvest attention is often not paid attention to, so the yield and quality of essential oils are inconsistent (Mansyur et al. 2015).

Yield is the ratio of the weight of the essential oil produced to the weight of the harvest before being distilled (Djoar et al. 2012). The higher yield will earn the higher essential oil produced. Oil yield is influenced by various factors, namely: extraction method (Wijaya et al. 2018), genetic factors, climate (Anggia et al. 2018), soil fertility, soil height (Sulaswatty et al. 2019), plant age, distillation method, location, and pest and disease attacks (Dacosta et al. 2017; Djoar et al. 2012). The amount of cineole content determines the quality of cajuput oil. The higher the cineole content indicates the better quality of cajuput oil. The main components of cajuput oil are cineole ($C_{10}H_{18}O$), pinene ($C_{10}H_{16}$), benzaldehyde (C_6H_5CHO), limonene ($C_{10}H_{16}$), and sesquiterpene ($C_{15}H_{24}$) (Khabibi 2011).

Several studies have reported that corn, soybeans, and rice have been planted among cajuput with an agroforestry pattern (Elonard 2015; Suryanto 2017). However, information on the amount of cajuput yield and cineole in ex-coal mining land with cajuput monoculture and agroforestry patterns has never been reported. Therefore, it is necessary to study the yield and content of cajuput cineole in the ex-coal mining land with agroforestry and monoculture patterns.

2. Materials and Methods

2.1. Research Location

The research was conducted on the 1.1 ha area of ex-coal mining land in Agroforestry Tupak Block 1, owned by PT. Bukit Asam, Tbk, Muara Enim, South Sumatra (**Fig. 1**). The ex-coal mining land is located in non-forest area or *Area Penggunaan Lain* (APL). The total area of agroforestry land specifically provided by the company is 20 ha and consists of 10 planting blocks. Yield and cineole testing was conducted at the Bogor Research Agency for Medicinal and Aromatic Plants (BALITTRO). The study was conducted in April 2017- March 2018.

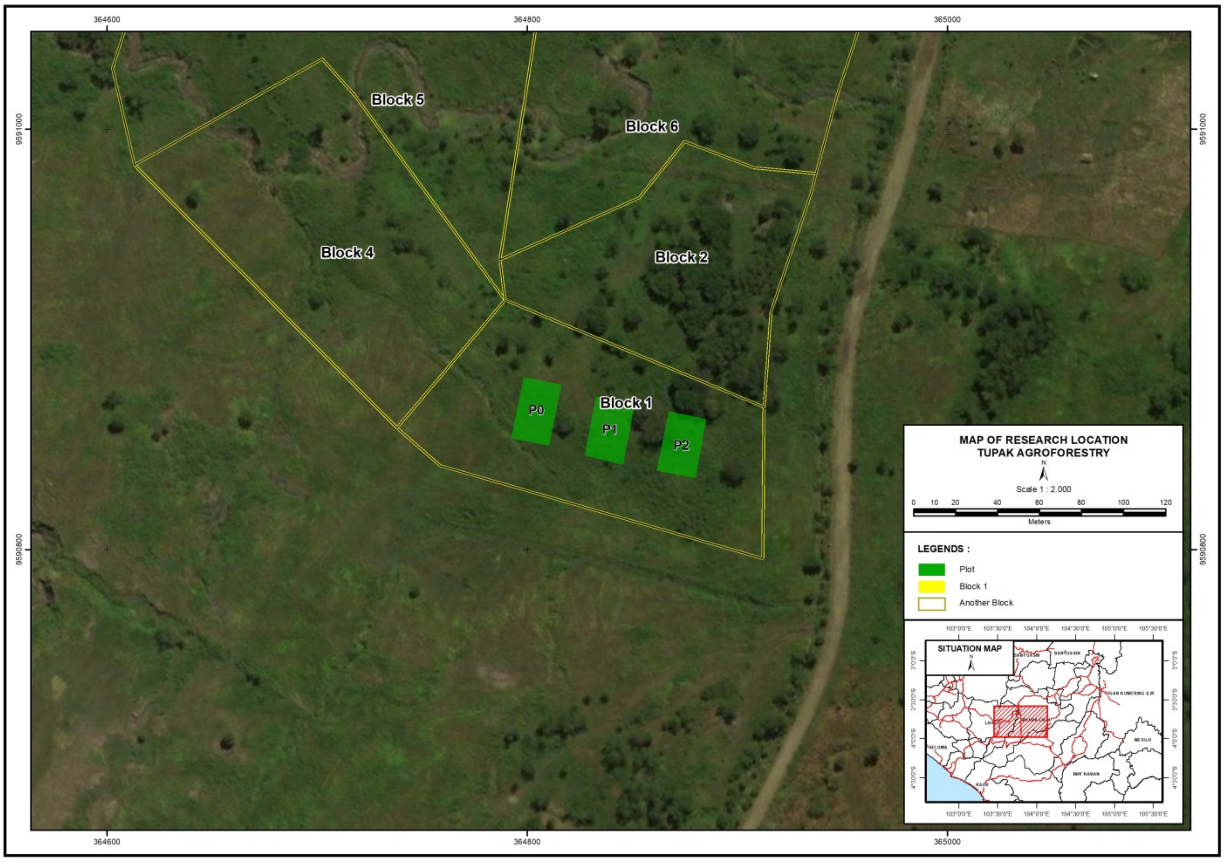

Fig. 1. Research location (3°42'3.6" South Latitude and 103°47'1.2" East Longitude).

2.2. Research Procedure

2.2.1. Cajuput monoculture area and agroforestry patterns

The cajuput monoculture area is located in Block 1 of Tupak Agroforestry with 1.1 ha. The main problems of this land are compact soil, low pH, lack of topsoil, and low organic C. The reclamation area was given 8 tons of compost, 2 tons of triple superphosphate (TSP), 250 kg of lime, and 12 tons of palm oil empty fruit bunches to overcome the soil problem. In 2015, this land was planted with cajuput with a spacing of 4 m × 2 m. In 2017, the research was started when cajuput was 1.5 years old. Before planting with lemongrass (*Cymbopogon nardus*), the ex-mining reclamation area has a pH of 6.02, organic C of 12.41%, total N of 0.17%, bulk density of 1.1 g/cm^3, cation exchange capacity of 55.05, and does not contain heavy metals.

The experiment was arranged using three combinations of cropping patterns, such as cajuput monoculture (P0), cajuput agroforestry with lemongrass G2 variety (P1), and cajuput agroforestry with Sitrona 2 Agribun variety (P2). Each combination of cropping patterns has 18 plots. Each plot has a size of 2 m × 2 m, consisting of 9 and 25 plants according to the lemongrass variety and spacing. The spacing between cajuput was 4 m × 2 m. The spacing designs for cajuput and lemongrass are presented in **Fig. 2** and **Fig 3**. The planting holes measuring 20 cm × 20 cm × 20 cm (length × width × depth) were then established according to the treatment. Compost fertilizer was given to lemongrass at a dosage of 0.3 kg/planting hole and 0.6 kg/planting hole according to the treatment. The research area of P0, P1, and P2 is presented in **Fig. 4**.

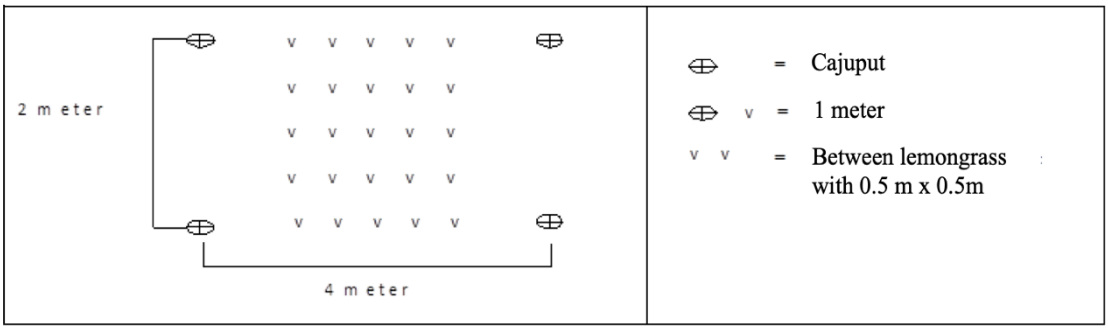

Fig. 2. Cajuput and lemongrass design with 0.5 m × 0.5 m spacing between lemongrass.

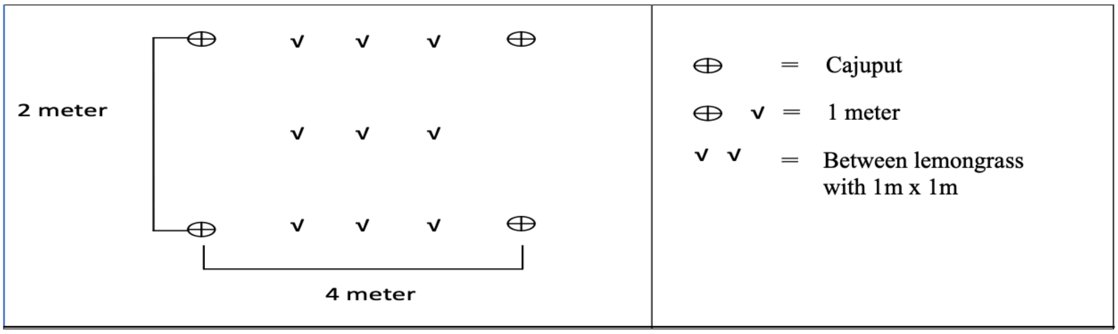

Fig. 3. Cajuput and lemongrass design with 1 m × 1m spacing between lemongrass.

Fig. 4. (A) Cajuput monoculture research area, (B) cajuput agroforestry with lemongrass G2 variety, and (C) cajuput agroforestry with Sitrona 2 Agribun variety.

2.2.2. Analysis of oil yield and cineole content

Cajuput leaves were harvested at two years or six months since the study began. First, fresh cajuput leaves were obtained by cutting down trees at the breast height (1.3 m). Then, the leaves and small twigs were harvested and weighed. Next, the cajuput leaves were air-dried (no more than two days) and distilled to get the yield. The oil yield was calculated using the following formula (Djoar et al. 2012):

$$\text{Yield (\%)} = \frac{\text{Weight of oil obtained (kg)}}{\text{Distilled leaves weight (kg)}} \times 100\% \quad (1)$$

This study distilled cajuput leaves at BALITTRO Bogor using steam distillation. The results of the cajuput yield were then carried out with a Gas Chromatography (GC) test to determine the percentage of cajuput cineole content.

2.3. Data Analysis

The study used a Split-split Plot Design with three factors, namely cropping pattern, compost, and spacing. Plant samples were repeated three times. Observational data were analyzed using Analysis of Variance (ANOVA) at a 95% confidence level to see differences between levels. If there is a significant effect on the research variables, the analysis continues with Duncan's Multiple Distance Test. Statistical data processing using the SAS 9.1 program.

3. Results and Discussion

3.1. Cajuput Yield

Treatment of cropping pattern, bokashi fertilizer dosage, and lemongrass spacing caused different responses to cajuput yield. The treatment of planting pattern and spacing had a significant effect on the yield of cajuput. On the other hand, fertilizer dosage treatment had no significant effect on yield. Likewise, the combination between treatments, namely cropping pattern, fertilizer dosage, and spacing, had no significant effect on the yield of cajuput.

The cajuput agroforestry with lemongrass Sitrona 2 Agribun variety (P2) had a higher yield of 2.84% compared to cajuput monoculture (P0) and cajuput agroforestry with lemongrass G2 variety (P1) of 2.74% and 2.13%, respectively. Cajuput yields in various treatments of cropping patterns are presented in **Table 1**.

Table 1. Cajuput yields in various cropping patterns

No	Cropping Pattern	Yield (%)
1	P0 (Cajuput monoculture)	2.74^{a}
2	P1 (Cajuput agroforestry with lemongrass G2 variety)	2.13^{b}
3	P2 (Cajuput agroforestry with lemongrass Sitrona 2 Agribun variety)	2.84^{a}

Note: The same letter after the number shows no significant difference at the 5% level.

Spacing treatment had a significant effect on the yield. The application of spacing of 0.5 m × 0.5 m increased the yield by 2.73% compared to a spacing of 1 m × 1 m of 2.40%. The amount of cajuput yield at the various spacing of lemongrass is presented in **Table 2**.

Tabel 2. Yield and cineole content of cajuput in various treatments of lemongrass spacing

No	Plant spacing	Yield (%)	Cineole (%)
1	Plant spacing of 0.5 m × 0.5 m	2.73^{a}	52.98^{a}
2	Plant spacing of 1 m × 1 m	2.40^{b}	46.37^{b}

Note: The same letter behind the number shows no significant difference at the 5% level.

3.2. Cajuput Cineole Content

The treatment of planting pattern and dosage of compost had no significant effect on the cineole content of cajuput. In contrast, plant spacing had a significant effect on the cineole content of the cajuput. Plant spacing of 0.5 m × 0.5 m increased the cineole content by 52.98% compared to a spacing of 1 m × 1 m by 46.37% (**Table 2**).

3.3. Discussion

Oil yield and cineole content are parameters that cannot be separated from essential oils. Generally, the higher yield will earn the higher cineole content. In addition, the amount of cineole content determines the quality of cajuput oil. The higher the cineole content indicated the better quality of cajuput oil (Aryani 2020; Khabibi 2011; Widiyanto and Siarudin 2013). The results showed that the treatment of cropping patterns, fertilizer dosage, and spacing caused different responses to the yield and content of cajuput cineole. Treatment of planting pattern and spacing increased the yield of cajuput. Cajuput agroforestry with lemongrass Sitrona 2 Agribun variety (P2) was able to increase the yield by 2.84%, which is higher than cajuput monoculture (P0), and cajuput agroforestry with lemongrass G2 variety (P1). It might be due to the presence of lemongrass in agroforestry areas causing cajuput to experience stress and producing higher secondary metabolites than cajuput in monoculture areas. The light and space stress obtained by cajuput in agroforestry areas caused cajuput to release secondary metabolites. Production of secondary metabolites was triggered by stress in plants. Increased radiation and low air temperature affect secondary metabolites (Perangin-angin et al. 2019).

The spacing of lemongrass increased the yield and cineole content of the cajuput. Treatment of spacing of 0.5 m × 0.5 m of lemongrass had a yield of 2.73% and cineole content of 52.98%, which was higher than the spacing of 1 m × 1 m. However, the distance was too tight between lemongrass, caused by competition for nutrients, water, light, and space (Ceunfin et al. 2017). As a result, the photosynthetic products were used more to meet the needs of shaded leaves than photosynthetic storage (Ceunfin et al. 2017). On the other hand, planting distances were too wide, reducing crop yields because the number of plant populations per unit area of land was minimal. Previous research supported that the yield of patchouli oil was higher at closer distances than at wide distances (Indara et al. 2016).

The amount of cineole content determines the quality of cajuput oil. The higher the cineole content indicated the higher the quality of the cajuput oil produced (Muyassaroh 2016). The quality standards of cajuput cineole based on SNI 06–3954–2014 are a super quality of > 60%, prime quality of 55–60%, and first quality of 50–<55. Based on SNI 06–3954–2014, the largest cajuput cineole produced with an agroforestry pattern is classified as the prime quality (57.18%). Cineole is a secondary metabolite of the cajuput. Secondary metabolites are produced as a defense mechanism from stress in the form of biotic and abiotic factors (Setyorini and Yusnawan 2016; Sopandie 2014). Abiotic stress on cajuput competes for light, water, nutrients, and space, while biotic stress on cajuput is in weeds, pests, and diseases (Setyorini and Yusnawan 2016). Similar studies reported that cineole content was found in cajuput aged 1-3 years, 57.87–70.05% (Subagio 2018), 91.50% resulted from variations in cajuput leaf dryness and distillation pressure variations (Muyassaroh 2016), and 22–64% were found in various locations in Maluku (Idrus et al. 2015).

The difference in the amount of yield and essential oil is due to the influence of several factors, namely genetic factors, cajuput tree varieties (Muyassaroh 2016), climate (Anggia et al. 2018), extraction method (Wijaya et al. 2018), and soil elevation (Sulaswatty et al. 2019), soil fertility, plant age, distillation method, material picking time and material handling before distillation (Nurdjannah 2006), location, and pest and disease attacks (Dacosta et al. 2017; Djoar et al. 2012). The oil yield and cineole content produced by cajuput with an agroforestry pattern were relatively high, indicating that cajuput can be developed using an agroforestry pattern on ex-mining land.

4. Conclusions

The cropping pattern of the cajuput agroforestry with lemongrass Sitrona 2 Agribun variety (P2) was able to increase the yield higher than that of the cajuput monoculture (P0) and the cajuput agroforestry with lemongrass G2 variety (P1). Plant spacing treatment of 0.5 m × 0.5 m increased the yield and cineole of the cajuput.

Acknowledgments

The authors thank the Environmental Manager of PT. Bukit Asam Tbk Muara Enim, South Sumatra for the facilities provided during this study. The authors also appreciate SEAMEO BIOTROP (Southeast Asian Regional Center for Tropical Biology) for providing research funding.

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