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Review of the Agronomic and Biochemical Potential of Eucalyptus Plants (*Melaleuca cajuputi*) as Essential Oil Producers

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ABSTRACT

This study explores the agronomic and biochemical potential of *Melaleuca cajuputi* (cajuput) through a comprehensive literature review of Indonesian research published between 2018 and 2024. The aim is to evaluate the effectiveness of various cultivation strategies particularly agroforestry systems, organic fertilization, and genetic improvement in enhancing the productivity and quality of cajuput essential oil. Results indicate that agroforestry patterns using intercropped citronella (Cymbopogon nardus) with Sitrona 2 Agribun variety yield the highest oil output (2.84%) and 1.8-cineole content (up to 52.98%). Organic fertilization using oil palm empty fruit bunch compost improved soil fertility and plant growth, while arbuscular mycorrhizal inoculation significantly enhanced seedling survival and leaf development. Furthermore, genetically selected varieties produced 1.2–1.3% oil yields with cineole levels reaching 68–75%. These findings demonstrate the synergistic benefits of integrated agronomic practices and plant breeding in producing high-quality cajuput oil for sustainable industrial and environmental applications.

Keywords: *Melaleuca cajuputi* , Agroforestry, Essential oil, Biochemical potential

I. INTRODUCTION

Indonesia is a megabiodiversity country that is rich in plants that produce essential oils (Erwin, 2023). One of them is *Melaleuca cajuputi* Powell or better known as Cajuputi L. or eucalyptus (Ariyanti, 2022). This plant belongs to the Myrtaceae family and is widely distributed in tropical and subtropical regions of Southeast Asia, including eastern Indonesia such as Maluku, Papua, and East Nusa Tenggara (Jannah et al., 2022) . *Melaleuca cajuputi* has an important role as a producer of high-value essential oils, which are obtained from the distillation of leaves and young twigs. (Wulanda and Waluyo, 2024).

Eucalyptus oil (cajeputi oil) produced from this plant has high economic and pharmacological value (Aryani, 2020). The main content of this oil is 1,8-cineol (eucalyptol) (Dwiarsa et al., 2021) monoterpene compounds are known to have antimicrobial, anti-inflammatory, analgesic, and expectorant activities (Sanjaya et al., 2020). In addition, eucalyptus oil is also used in various industries, ranging from pharmaceutical products, cosmetics, to aromatherapy, making it a strategic commodity for further development (Farida Aryani, 2020).

In Indonesia, *Melaleuca cajuputi* cultivation has become a form of agro-industry that supports local economic development and environmental preservation. (Farida Aryani, 2020). This plant is able to grow on marginal land and is resistant to extreme environmental conditions, such as acidic soil and dry land, so it has great potential for use in critical land rehabilitation and reforestation programs. (Ummah, 2019). In addition, its high productivity and relatively fast harvest cycle make it an ideal choice for sustainable development (Roidah, 2019) .

Despite having many advantages, the development of *Melaleuca cajuputi* commodities still faces various challenges, ranging from the limitations of traditional refining technology, low oil quality due to genetic variation among plants, to the lack of research support in breeding superior varieties and improving production efficiency (Mansur et al., 2022). However, most existing studies have focused only on the chemical characterization of cajuput oil and its antimicrobial properties,while comprehensive evaluations combining agronomic, biochemical, and genetic approaches remain limited. This indicates a research gap in understanding how integrated cultivation systems, such as agroforestry combined with organic fertilization and mycorrhizal inoculation, can synergistically improve both yield and oil quality. Therefore, a comprehensive scientific and technological approach is needed, starting from the selection of superior genotypes, improvement of cultivation techniques, and optimization of essential oil extraction processes (Roidah, 2019).

With the more increasing need will product natural friendly environmental and efficient in a way economy , development *Melaleuca cajuputi* as source oil essential oil own high urgency (Cici, 2023) Utilization potential plant This No only answer challenge industry material standard experience (Wattimena et al., 2021).

II. METHODS

This literature review was conducted by collecting and analyzing research articles published between 2018 and 2024. Data sources were obtained from various national scientific journals relevant to the topic of *Melaleuca cajuputi* and its antimicrobial activity. Inclusion criteria included studies conducted in Indonesia, focusing on Melaluca cajuputi essential oil, and evaluating antibacterial or antifungal activity.

The article search process is carried out through national journal databases such as Jurnal Cendekia Kimia, EduMatSains, and Jurnal Biologi Udayana. Keywords used in the search included "*Melaleuca cajuputi* ", "essential oil", "antimicrobial", "antibacterial", and "antifungal". Articles that met the inclusion criteria were then analyzed to identify extraction methods, concentrations of active compounds, and antimicrobial activity test results.

Data analysis was carried out descriptively by comparing existing research results. The main focus is on the identification of active compounds in M. cajuputi essential oil and its effectiveness against various pathogenic microorganisms. In addition, the practical application of this essential oil in various antimicrobial product formulations was also evaluated.

III. RESULTS AND DISCUSSION

Research on post-mining land shows that agroforestry patterns with interplanting of lemongrass (Cymbopogon nardus) (Farhannudhin et al., 2021) , specifically using the Sitrona 2 Agribun variety, provided the highest yield of eucalyptus oil (cajuput) of 2.84%, with a 1.8 cineole content reaching 50.70%. (Wahyuni & Taiyeb, 2021) far exceeding the monoculture or agroforestry system with the G2 variety; in fact, the lemongrass planting distance of 0.5 × 0.5 m increased cineole levels by up to 52.98% confirmed that interplanting of lemongrass was very effective in improving the quality of cajuputi oil, while the fertilizer dose had no significant effect on the yield or cineole content. Rahmah et al.,(2022) . This finding indicates that interplanting lemongrass can improve the quality of cajuputi oil, especially cineole content, without any significant effect from the dose of fertilizer used. Mansur et al., (2022) .

Compost studies show that the application of 5 kg of oil palm empty bunch compost per plant for 1–2 year old seedlings, and 7.5 kg for 3 year old plants (Manek et al., 2023) , improving soil quality including increased pH, organic C, CEC, total N, and total K which then supports the growth of the height and diameter of eucalyptus plants on ex-mining land Wedhana et al., (2018) . The increase in new stem thickness appeared significant, although the width of the plant crown did not change, confirming that compost mainly supports vertical growth . Amirullah et al., (2021) also reported similar findings confirming that TKKS compost is effective in supporting the vegetative growth of eucalyptus plants. Can seen in table III.1 comparison plant wood white with different parameters.

Table III.1 Comparison plant wood white (*Melaleuca cajuputi*)

Parameter	**System / Treatment**	**Oil Yield**	**Cineole Content-**	**Source**
Agroforestry + Citrona 2 Agribun	Agroforestry (lemongrass distance 0.5×0.5 m)	2.84%	50.70%	(Jannah et al., 2022)
Lemongrass 0.5×0.5 m spacing	Agroforestry	2.73%	52.98%	(Wirabuana et al., 2021)
TKKS compost (5–7.5 kg/plant)	Post-mining media	—	—	(Taopik et al., 2022)
Compost + mycorrhiza	Post-mining media	—	—	(Gabriella et al., 2024)
General agroforestry	Agroforestry vs monoculture	—	+~50 %	(Pramudi et al., 2024)
Superior varieties (breeding)	Superior garden / genetic varieties	1.2–1.3%	68–75 %	(Sari et al., 2021)

Furthermore, the role of arbuscular mycorrhiza has been shown to be significant in increasing seedling resistance. with survival reaching 100% and the number of seedling leaves, especially when combined with compost; this combination greatly supports the adaptation of seedlings in challenging post-mining media. Salsabila & Wulandari, (2023) . Study by Zulkarnain, (2022) also noted an increase in the number of leaves and seedling resistance thanks to the provision of 167 g of compost per *polybag* , strengthening the ecosystem rehabilitation strategy through this combination method.

Beside benefit agronomically, the use of mycorrhiza arbuscular also has an impact positive to activity physiological plants , such as improvement photosynthesis and efficiency water use (Muharyani & Abdillah, 2022) . Mycorrhiza help repair structure land with increase aggregation land through the glomalin compound produced , so that root plant can develop more optimal (Sari et al., 2021) . In condition land used mines that are generally own texture land dense and poor in material organic , existence mycorrhiza play a role important in create condition more rhizosphere friendly for growth root (Amirullah et al., 2021) . This is make combination mycorrhiza and compost No only strengthen resilience seed in a way physical , but also creates foundation more biological and chemical stable for plant wood white For grow and produce metabolit secondary such as cineole optimally (Wattimena et al., 2021) .

In terms of oil quality, agroforestry cultivation has been proven to create more optimal microclimate conditions and soil fertility compared to monoculture, so that the yield and content of 1.8 –cineole experienced a significant increase, for example, cineole levels increased by around 50% compared to classical monoculture (Febriandy et al., 2022) . Several superior varieties resulting from genetic breeding achieve yields of 1.2–1.3% and cineole content of up to 68–75% in superior gardens. Kissinger & Budi, (2024) . These findings indicate that integration between agroforestry practices, soil improvement, and genetic improvement can produce high-quality eucalyptus oil. (Ma'ruf et al., 2023)

IV. CONCLUSION

The agroforestry cultivation pattern using inter-planting of lemongrass (Cymbopogon nardus) with the Sitrona 2 Agribun variety has been proven to effectively increase the oil yield of *Melaleuca cajuputi* up to 2.84% and the 1,8-cineole content by 50.70% (Hidayat et al., 2025). The lemongrass planting distance of 0.5 × 0.5 m was even able to raise the cineole content up to 52.98%, while fertilizer dosage showed no significant effect, confirming that the main agronomic interventions lie in the agroforestry design and the selection of superior varieties. Organic fertilization using empty fruit bunch compost of oil palm also improved soil parameters such as pH, organic carbon, and total nitrogen, which support vertical plant growth, although it did not affect canopy width. Meanwhile, arbuscular mycorrhizal inoculation increased seedling survival up to 100% and the number of seedling leaves, thereby strengthening post-mining land restoration strategies.

In addition, the development of superior varieties through genetic breeding provides a synergistic effect on oil quality, with yields reaching 1.2–1.3% and cineole levels up to 68-75%. Overall, the combination of agroforestry cultivation, organic fertilization, mycorrhizal inoculation, and genetic improvement shows significant synergy in increasing the productivity and quality of M. cajuputi oil. This strategy is considered commercially feasible and sustainable, particularly for the rehabilitation of critical post-mining lands.

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