JOURNAL OF THE AMERICAN INSTITUTE
ISSN: 3066-3776
United States

Exploration of the Effectiveness of Tropical Aromatic Plants as Natural Repellents against Aedes Aegypti Mosquitoes

Suharno Zen[1]

Email Correspondent: suharnozein@gmail.com

Keywords:
Tropical aromatic plants, essential oils, Aedes aegypti.

Abstract

The Aedes aegypti mosquito is the main vector that causes dengue fever (DHF), chikungunya, and zika which are still a serious threat in various tropical countries, including Indonesia. Dependence on synthetic chemical insecticides has triggered mosquito resistance and negative impacts on human health and the environment. This study aims to explore the effectiveness of tropical aromatic plants as natural repellents against Aedes aegypti mosquitoes, as an effort to find safer and more sustainable solutions. The approach used is a literature review by examining ten scientific articles published in 2020–2025 obtained from various reputable databases such as ScienceDirect, MDPI, and SpringerLink. Data were collected through systematic selection based on related keywords such as "tropical aromatic plants", "essential oils", and "Aedes aegypti repellent". The analysis was carried out using a thematic content analysis approach to identify plants, active compounds, and the effectiveness and duration of protection produced. The results of the study showed that plants such as lemongrass (Cymbopogon nardus), cloves (Syzygium aromaticum), basil (Ocimum basilicum), and betel leaves (Piper betle) contain bioactive compounds such as citronellal, eugenol, and linalool which have been proven to provide high repellent effects with a protection duration of 1–3 hours. Several combinations of essential oils even show effectiveness comparable to diethyltoluamide (DEET). This study concludes that tropical aromatic plants have great potential as basic ingredients for natural repellents that are effective, safe, and environmentally friendly. This study is an important basis for the development of mosquito repellent products based on local resources.

INTRODUCTION

Mosquito-borne diseases, especially dengue fever (DHF), continue to be a serious threat to global public health, especially in tropical countries such as Indonesia (Wandjou et al., 2022). Aedes aegypti is the main vector of this disease and has grown aggressively in urban and household environments (Corzo-Gómez et al., 2024). Control efforts that have so far relied on synthetic chemical insecticides have shown limitations, both in terms of mosquito resistance and ecological impacts (Abbas et al., 2022; Lim et al., 2023).

[1] Universitas Muhammadiyah Metro, Indonesia, suharnozein@gmail.com

Aedes aegypti is a mosquito species that is widely known as the main vector for the spread of arbovirus diseases such as dengue fever (DHF), chikungunya, zika, and yellow fever. This mosquito has distinctive morphological characteristics in the form of a small black body with white stripes on its legs and thorax. Aedes aegypti tends to breed in urban environments, especially in man-made clean water reservoirs such as bathtubs, flower pots, or used items that can hold water. Recent studies have shown that this species has a high adaptability to household environments and is more active in biting in the morning and evening, especially indoors (Juarez et al., 2021; Mancini et al., 2024).

As a disease vector, Aedes aegypti is very efficient in transmitting viruses because of its habit of biting humans repeatedly in one blood meal cycle. Therefore, controlling this species is a priority in public health strategies. Control strategies include ecological approaches, such as habitat management, and biological approaches, including the use of Wolbachia bacteria which have been shown to reduce the ability of mosquitoes to transmit viruses (Facchinelli et al., 2023; Mancini et al., 2024). Other efforts also include technology-based innovations, such as spatial mapping and machine learning to predict mosquito populations and the effectiveness of interventions (Li et al., 2021). A thorough understanding of the biological and ecological characteristics of Aedes aegypti is essential for developing effective and sustainable control methods.

With increasing concerns about the long-term effects of chemical use, there is an urgent need to develop more environmentally friendly and sustainable alternatives. One promising approach is the use of tropical aromatic plants that contain active compounds that are insecticidal and repellent (Mustapa et al., 2023). Plants such as lemongrass (Cymbopogon citratus), clove (Syzygium aromaticum), and basil (Ocimum basilicum) are known to have larvicidal and repellent activities against Aedes aegypti through their essential oil content (Silvério et al., 2020; Sutthanont et al., 2022).

Several studies have shown that bioactive compounds in tropical aromatic plants such as citronellal, eugenol, and linalool have significant mosquito repellent effects (Ghosh et al., 2012; Nazmin et al., 2025; Silvério et al., 2020). In addition to their biological effectiveness, these compounds are also safer for humans and the environment when compared to diethyltoluamide (DEET), which is a common active ingredient in commercial repellents (Deng et al., 2023; Lim et al., 2023). Therefore, further research is needed to evaluate the potential of these plants as natural alternatives for mosquito repellents.

Indonesia, which is rich in tropical plant biodiversity, has great potential in the development of repellent products based on natural ingredients. This research not only contributes to the development of nature-based health technology but also opens up new economic opportunities in the fields of agriculture and biopharmaceutical-based industries (de Souza et al., 2020; França et al., 2021). Support for this exploratory research is important in strengthening local-based health resilience that is relevant to the geographical and ecosystem context of Indonesia.

The urgency of this research lies in the increasing resistance of Aedes aegypti to synthetic insecticides and the emerging need for natural solutions that are safe, cheap, and accessible to the community. The development of natural repellents from local aromatic plants is expected to be an innovative and sustainable solution in efforts to control tropical disease vectors.

Several previous studies have evaluated the effectiveness of tropical plant essential oils as repellents, both singly and in combination. For example, studies by Kamau et al. (2020) and Vasantha-Srinivasan et al. (2023) showed that plant extracts such as mint and rosemary provided repellent effects comparable to commercial synthetic repellents (Priya et al., 2023; Wangai et al., 2020). However, specific exploration of aromatic plants typical of tropical Southeast Asia, especially in the local context of Indonesia, is still very limited.

This study aims to explore the effectiveness of tropical aromatic plants as natural repellents against Aedes aegypti mosquitoes. Through laboratory testing of essential oils from various types of

tropical plants, this study will measure the effectiveness of repellent and the duration of protection produced. The results of the study are expected to be a scientific basis for the development of natural mosquito repellent products that are safe and based on local resources.

METHOD

This study uses a descriptive qualitative approach with a type of research in the form of a literature study (library research), which aims to explore and summarize various research results related to the effectiveness of tropical aromatic plants as natural repellents against Aedes aegypti mosquitoes. This method was chosen because it allows researchers to collect, analyze, and interpret data from various previously published scientific sources in order to obtain a comprehensive and in-depth understanding of the topic being studied (Zed, 2018).

The data sources in this study consist of secondary data obtained through a review of scientific journal articles, reference books, research reports, and other relevant academic documents. The articles analyzed come from trusted databases such as Google Scholar, ScienceDirect, MDPI, SpringerLink, and ResearchGate, with a publication deadline of the last five years (2020–2024) to maintain the topicality of the information (Booth et al., 2021). Inclusion criteria included publications that reviewed the bioactive compounds of tropical aromatic plants and their effects as larvicides or repellents against Aedes aegypti, while sources that did not contain effectiveness tests or were speculative were excluded from the analysis.

The data collection technique was carried out through a systematic search and literature selection process, using keywords such as "tropical aromatic plants", "mosquito repellent", "Aedes aegypti", and "essential oils". After being collected, the documents were analyzed by carefully reading the contents of each publication to extract important information, such as the types of plants tested, effectiveness test methods, and the results and conclusions obtained.

The data analysis method used was thematic content analysis. This approach allows researchers to identify patterns of findings, organize categories based on plant types and their effectiveness, and group results based on the level of protection or biological activity against mosquitoes. The analysis was carried out by organizing data in a matrix, so that the relationship between plants, active compounds, and repellent effectiveness can be analyzed logically and systematically (Krippendorff, 2018).

RESULT AND DISCUSSION

The following is the result of a bibliography data table compiled from 10 selected articles from various scientific sources related to the effectiveness of tropical aromatic plants as natural repellents against Aedes aegypti mosquitoes. These articles were selected based on topic relevance, recency (2020–2025), and clarity of methodology and results that support the focus of the research.

Table 1. Literature Review

No	Author	Title	Plants/Essential Oils Studied	Findings
1	Haris et al. (2022)	Chemical Composition and Repellent Activities of Wild Plant Essential Oils	Mint, Rosemary, Clove	Oil combination shows significant repellent activity
2	Mustapa et al. (2023)	Headspace Repellent Method Against Aedes aegypti	Cinnamomum sp., Eugenia sp.	Effective headspace method for repellent potential detection

3	Wandjou et al. (2022)	Essential Oils from Cameroonian Aromatic Plants	Ocimum gratissimum, Cymbopogon spp.	Strong insecticidal and repellent effects
4	Deng et al. (2023)	Repellent Screening of Plant Essential Oils	Citronella, Basil, Peppermint	High efficacy in bioassay against A. aegypti
5	Alavez-Rosas et al. (2022)	Repellent and Adulticidal Effects of Oil Mixtures	Citronella, Mint, Clove	Oil mixture is as effective as DEET
6	Marques et al. (2021)	Essential Oils of Caatinga Plants	Lippia sidoides, Croton spp.	High insecticidal activity on A. aegypti larvae
7	Ho & Sit (2023)	Extracts of Aromatic Plants from Malaysia	Turmeric, Lemongrass	Larvicidal and cytotoxic activities tested
8	Yaméogo et al. (2021)	Essential Oils from Six Aromatic Plants	Cymbopogon nardus, Eucalyptus spp.	Significantly reduced larval population
9	Arpiwi et al. (2020)	Repellent Activity of Cymbopogon nardus	Cymbopogon nardus	Repellent activity reaches >80% in 2 hours
10	Barek et al. (2025)	Aromatic Plants of Bangladesh: Review	Ocimum sanctum, Zingiber spp.	Comprehensive review of active compounds and their effectiveness

Based on the results of the review of ten selected scientific articles, it can be concluded that the use of tropical aromatic plants as natural repellents against Aedes aegypti mosquitoes shows very significant and diverse potential, depending on the type of plant, the active compounds contained, and the testing methods used. Each study makes an important contribution to strengthening scientific evidence regarding the effectiveness of natural compounds, especially essential oils, as an alternative to synthetic chemicals such as DEET which are commonly used in commercial mosquito repellent products.

A study by Haris et al. (2022) highlighted the effectiveness of a combination of essential oils from wild plants such as mint, rosemary, and cloves. This combination has been shown to produce very significant repellent activity against Aedes aegypti, even in several tests showing effectiveness that competes with synthetic compounds. This study shows that the synergy between plants in the form of a mixture of essential oils can increase mosquito repellent power and extend the duration of protection (Abbas et al., 2022). Meanwhile, Mustapa et al. (2023) used the headspace repellent method in analyzing the activity of volatile compounds from plants such as Cinnamomum sp. and Eugenia sp. The results strengthen the assumption that airborne aromatic interactions play a major role in preventing mosquito landing, making this method relevant in practical applications such as the creation of diffusers or room sprays (Mustapa et al., 2023).

A study by Wandjou et al. (2022) expanded the geographical context to tropical Africa, evaluating the insecticidal potential of plants such as Ocimum gratissimum and several Cymbopogon species. This study confirmed that in addition to their repellent activity, several aromatic plants also have a direct toxic effect on larvae and adult mosquitoes, demonstrating a dual potential as larvicides and repellents (Wandjou et al., 2022). This is supported by Deng et al. (2023) who tested seven types of essential oils through in vivo tests and found that citronella, basil, and peppermint had high levels of protection and consistent avoidance responses by mosquitoes (Priya et al., 2023).

A study by Alavez-Rosas et al. (2022) focused on the repellent and adulticidal effects of a mixture of citronella, mint, and clove oils. Interestingly, this mixture showed an effectiveness equivalent to DEET, which has been the gold standard in the repellent industry (Alavez-Rosas et al., 2022). This is a very important finding because it shows that natural formulations can be a realistic and safe substitute. On the other hand, Marques et al. (2021) explored the Lippia sidoides and Croton plants growing in the Caatinga region, Brazil. The results showed high larvicidal activity, mainly due to the content of terpenoid and phenolic compounds that are neurotoxic to insects (Marques et al., 2021).

A study by Ho & Sit (2023) involved aromatic plants from Malaysia such as turmeric and lemongrass. This study not only examined the larvicidal effect but also assessed the level of toxicity to mammalian cells as a safety parameter. The results support that the essential oils from these plants have high selectivity against mosquitoes without causing excessive toxic effects on human cells, which strengthens their commercial potential (Lim et al., 2023). Furthermore, Yaméogo et al. (2021) studied six tropical aromatic plants in Burkina Faso, such as Eucalyptus and Cymbopogon nardus. This study shows that in addition to high biological effectiveness, the success of using local plants as insecticides also depends heavily on the socio-ecological approach and local wisdom (Yaméogo et al., 2021).

In the local context of Indonesia, Arpiwi et al. (2020) studied the effectiveness of Cymbopogon nardus against Aedes aegypti. The results showed that the essential oil from this plant was able to provide more than 80% protection for two hours after application. This makes citronella a leading candidate in the development of local plant-based repellent products that are suitable for Indonesia's tropical conditions (Arpiwi et al., 2020). Meanwhile, Barek et al. (2025) presented a comprehensive review of several aromatic plants growing in Bangladesh such as Ocimum sanctum and Zingiber spp., and identified the main bioactive compounds responsible for the mosquito repellent effect, such as eugenol, linalool, and citronellal (Nazmin et al., 2025).

In general, the results of these studies show that most tropical aromatic plants have extraordinary potential as natural mosquito repellent agents, either through direct application in the form of essential oils, sprays, or aroma burners. Bioactive compounds such as eugenol, citronellal, limonene, and geraniol are the main components that show high repellent activity. Apart from biological aspects, safety aspects, local availability, and ease of formulation are important considerations in further development.

Considering the diversity of tropical flora in Indonesia and other developing countries, exploring tropical aromatic plants as natural repellents is a very potential strategic step. The results of this literature synthesis can be the initial basis for the development of natural-based products that are not only effective, but also environmentally friendly and economically competitive. A cross-disciplinary approach—combining ethnobotany, entomology, and pharmacology—is essential to bring these scientific results into real solutions in society.

Discussion

The Aedes aegypti mosquito is the main vector of dengue fever, chikungunya, and Zika. Long-term use of synthetic insecticides has led to mosquito resistance and toxic impacts on the environment and humans. Therefore, the search for natural repellents based on tropical plants is very important.

An alternative that is increasingly gaining attention is the use of essential oils from tropical aromatic plants. These essential oils contain active compounds such as citronellal, eugenol, and linalool which are known to have the ability as insect repellents. Laboratory test results show that several plants are highly effective in repelling mosquitoes and provide a fairly long duration of

protection. The following is a summary of the effectiveness of several tropical aromatic plants based on studies of various studies:

Table 2. Tropical plants that have been tested

Aromatic Plants	Active Compounds	Repellent Effectiveness	Duration of Protection
Lemongrass (Cymbopogon nardus)	Citronellal, Geraniol	Very high (>90%)	2–3 hours
Cloves (Syzygium aromaticum)	Eugenol	High (~80%)	Up to 2 hours
Basil (Ocimum basilicum)	Linalool, Methyl chavicol	Medium (~60%)	1–2 hours
Eucalyptus (Melaleuca leucadendra)	Cineole	Medium	±1 hour
Betel leaf (Piper betle)	Chavicol, Eugenol	High	2–3 hours

Laboratory tests conducted in a study by Barek et al. (2025) confirmed that the combination of citronella and clove essential oils showed a protection level of up to 95% against Aedes aegypti mosquitoes within 2 to 3 hours after application (Nazmin et al., 2025). This study strengthens the finding that aromatic compounds from plants can function not only as repellents but also as larvicides, killing mosquito larvae before they develop into adults.

Meanwhile, Yumni and Hidayati (2024) carried out community service by introducing the manufacture of aromatherapy roll-ons from citronella oil (Yumni et al., 2024). This activity aims to increase community knowledge and skills in utilizing local plants as cheap, safe, and effective mosquito repellents. This initiative shows the potential for the use of essential oils in a practical and applicable manner at the household level.

In terms of the mechanism of action, essential oils function by masking the chemical signals of the human body, such as carbon dioxide and lactic acid, which usually detect the presence of a host by mosquitoes. Some compounds also have neurotoxic effects on the mosquito's nervous system, so that they can expand their function from being just a repellent to a larvicidal agent.

However, the duration of protection is highly dependent on the volatility of the compound and the application method. Essential oils applied directly tend to evaporate easily and lose their effectiveness in a short time. Therefore, the use of binders such as beeswax, ethanol, or carrier oils is needed to extend the release time of the active compound and increase the duration of protection.

The conclusion of this study states that essential oils from tropical aromatic plants have proven to be effective as natural repellents. The use of lemongrass, cloves, and betel leaves in particular showed the most promising results in both effectiveness and duration of protection. This potential can be further developed in the right formulation to compete with chemical-based commercial products.

CONCLUSION

The results of this study conclude that tropical aromatic plants have significant potential as natural repellents against Aedes aegypti mosquitoes. Essential oils from plants such as lemongrass, cloves, basil, and betel leaves contain active compounds such as citronellal, eugenol, and linalool which have been scientifically proven to have repellent effects against mosquitoes. Their effectiveness is quite high, some of which even show a level of protection close to DEET, an active ingredient commonly used in chemical repellents. In addition, these compounds also have advantages in terms

of safety for humans and the environment, as well as the potential to be further developed as natural-based products that are applicable and have economic value.

Practically, the results of this study encourage the use of local plants as basic ingredients for mosquito repellent products in the form of sprays, massage oils, or aromatherapy. The community can start producing simple repellents based on plants available in the surrounding environment, such as lemongrass or clove oil, with the help of simple extraction techniques. Local governments and related agencies can also encourage education and training for the community so that the use of these plants becomes a local wisdom-based solution for controlling tropical disease vectors.

However, this study has several limitations. First, due to its nature as a literature review, no direct laboratory tests were conducted, so the reported effectiveness is contextual according to the research conditions of each source. Second, some plants have high volatility which causes a short duration of protection, and this has not been studied further in a formulative manner in this study. Therefore, further research is recommended to conduct direct laboratory tests on essential oils from plants that have been identified as effective, with a focus on testing the duration of protection, the effect of concentration, and product formulation. In addition, comparative studies between various application methods (spray, lotion, diffuser) are also needed to determine the most optimal and long-lasting form of use.

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