



MEDICINAL PLANTS FOR MOSQUITO VECTOR CONTROL: AN UPDATED REVIEW OF PHYTOCHEMICAL-BASED PEST MANAGEMENT STRATEGIES

¹Jenifer E, ²Lavanya R, ³Anitha W, ⁴Nivedha S and ^{5*}Aswini L

¹PERI College of Nursing, Chennai - 48, Tamil Nadu, India

²PERI College of Physiotherapy, Chennai – 48, Tamil Nadu, India

³PERI College of Pharmacy, Chennai - 48, Tamil Nadu, India

⁴PERI Institute of Technology, Chennai - 48, Tamil Nadu, India

^{5*}PERI College of Arts and Science, Chennai - 48, Tamil Nadu, India

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ABSTRACT

Mosquito-borne diseases such as malaria, dengue, and lymphatic filariasis continue to pose significant global public health challenges, particularly in tropical and subtropical regions. The widespread use of synthetic insecticides has led to environmental toxicity, increased resistance among mosquito populations, and adverse effects on non-target organisms. In response, there is growing interest in exploring phytochemicals derived from medicinal plants as eco-friendly alternatives for vector control. This review compiles and critically analyzes current research on plant-based larvicides and repellents, with a focus on species such as *Leucas aspera*, *Tridax procumbens*, *Ocimum sanctum*, *Hyptis suaveolens*, and *Mentha arvensis*. These plants exhibit significant bioactivity against key mosquito vectors including *Aedes aegypti*, *Anopheles stephensi*, and *Culex quinquefasciatus*. The mechanisms of action—ranging from enzyme inhibition to membrane disruption—are discussed, along with the roles of essential oils, flavonoids, alkaloids, and other bioactive constituents. Despite promising laboratory results, challenges such as low stability, inconsistent phytochemical yields, and lack of formulation standards hinder commercial application. The review concludes by emphasizing the need for interdisciplinary research, including nanotechnology integration, synergistic formulations, and standardized bioassays, to facilitate the transition of plant-based pesticides into sustainable public health tools.

Keywords: Medicinal plants, Mosquito control, Phytochemicals, Larvicides, Vector-borne diseases, Essential oils.

INTRODUCTION

Mosquito-borne diseases continue to be a major public health threat, affecting billions of people globally and causing millions of deaths annually. Vectors such as *Aedes aegypti*, *Anopheles stephensi*, and *Culex quinquefasciatus* are responsible for transmitting life-threatening infections including dengue, malaria, chikungunya, Zika virus, and lymphatic filariasis. Conventional vector control strategies rely heavily on synthetic insecticides and larvicides. While effective in the short term, these chemical agents pose significant risks including environmental pollution, development of insecticide resistance, and toxicity to non-target species and humans. In response to these limitations, there is a growing interest in the use of phytochemicals

derived from medicinal plants as a safer and more sustainable alternative. Medicinal plants have been used traditionally in many cultures for their therapeutic and insecticidal properties. Their bioactive constituents—such as alkaloids, flavonoids, terpenoids, saponins, and essential oils—have shown considerable potential as larvicidal and repellent agents in both laboratory and semi-field conditions.

This review aims to provide a comprehensive overview of medicinal plant species that exhibit mosquitocidal activities, elucidate their mechanisms of action, evaluate their potential integration into vector management programs, and identify challenges and research gaps that must be addressed to facilitate their broader application.

*Corresponding Author: Aswini L, PERI College of Arts and Science, Chennai – 48, Tamil Nadu, India. Email: publications@peri.ac.in.

Numerous studies have demonstrated the potent larvicidal properties of medicinal plant extracts against major mosquito vectors such as *Aedes aegypti*, *Anopheles stephensi*, and *Culex quinquefasciatus*. Kamaraj *et al.* investigated a range of plant species and confirmed their effectiveness in inducing mortality in both *Anopheles* and *Culex* larvae. Similar outcomes were reported by Anees, who demonstrated strong activity of *Ocimum sanctum* against *Aedes* and *Culex* species. Elango *et al.* and Anuradha *et al.* also validated the larvicidal effect of indigenous plant extracts against *Anopheles subpictus* and *Culex tritaeniorhynchus*. Additionally, Ramar *et al.* highlighted the dual efficacy of *in silico* and *in vivo* methods using *Ocimum sanctum* oil, supporting the mechanistic understanding of plant-based larvicidal action.

The role of essential oils in mosquito control has been studied extensively. Conti *et al.* and Morais *et al.* found that essential oils from Mediterranean and Brazilian plants exhibit significant larvicidal effects against *Aedes albopictus*. Park *et al.* demonstrated that plant oils such as

garlic and horseradish function as effective fumigants against pests, including mosquitoes. Ojo and Egunjobi reported that essential oils from *Ocimum basilicum* and *Mentha piperita* showed high toxicity toward *Aedes* larvae. The insecticidal efficacy of plant-based compounds is attributed to their diverse bioactive constituents—flavonoids, alkaloids, terpenoids, and saponins. Biswas *et al.* reviewed the various modes of action, such as enzyme inhibition and neurotoxic effects, that disrupt mosquito larval development. Sanchez *et al.* emphasized the potential of phytochemicals in essential oils as synergistic agents in mosquito control strategies. Several studies compared the larvicidal efficacy of different plants. Adhikari and Chandra evaluated *Swietenia mahagoni* and found it to be effective against *Anopheles stephensi* in terms of smoke toxicity and emergence inhibition. Ghosh *et al.* investigated *Solanum nigrum* and its berry extracts, which showed strong larvicidal action against *Culex* vectors. Ghose *et al.* explored the use of salicylic acid derivatives against filarial vectors, indicating the potential of plant-inspired chemical analogs.

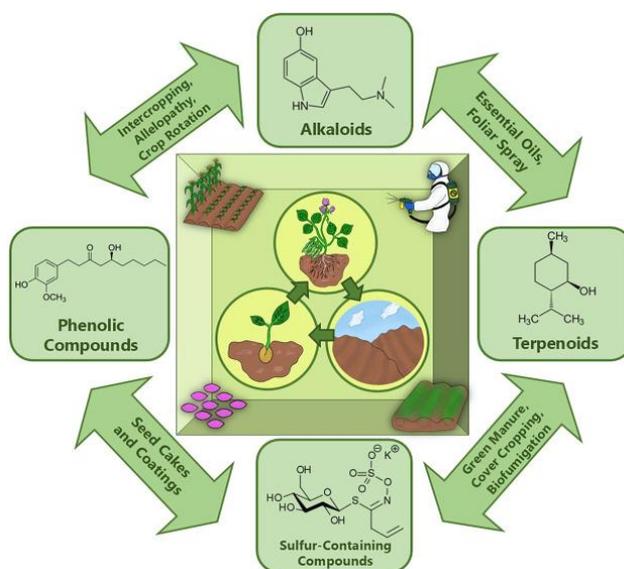


Figure 1. Phytochemical Applications in organic Farming.

Sukumar *et al.* and Kishore *et al.* provided comprehensive reviews of botanical derivatives for mosquito control, summarizing decades of phytochemical exploration. Chandra *et al.* and Sathe and Girhe documented traditional knowledge systems supporting the use of herbs for mosquito management. Tennyson *et al.* also confirmed the ovicidal effect of *Ageratum houstonianum*, reinforcing the value of ethnobotanical approaches in integrated vector management. While efficacy is promising, formulation challenges persist. Kamaraj and Chandra successfully synthesized silver nanoparticles using *Drypetes roxburghii*, offering a modern nanotechnological approach to improve stability and efficacy. Ram Mohan and Ramaswamy and Mondal and Chandra investigated underutilized plant and

marine resources for alternative bioinsecticides. Ghosh *et al.* examined the ecological approach of using fish predators for mosquito control. Inziani *et al.* focused on environmental tools that integrate plant-derived larvicides into sustainable public health strategies. Although outside direct vector control, studies like Chang and Ahn have shown that plant-derived volatiles (e.g., anethole from *Foeniculum vulgare*) have fumigant properties, which could be repurposed for mosquito vector control. Mahalakshmi *et al.* explored the health risks associated with inhalation of volatile paint fumes. Their review highlighted respiratory consequences such as reduced lung function and long-term pulmonary disorders, stressing the necessity for safety regulations and protective measures for

workers and exposed populations. Farheen *et al.* investigated medicinal plants as therapeutic candidates for hepatocellular carcinoma. Their mini-review pointed out the hepatoprotective properties of phytochemicals and their potential to provide affordable, accessible alternatives to conventional cancer treatments. Geetha *et al.* used computational methods to evaluate natural bioactive compounds and their interactions with mosquito proteins. This research provides insights for novel insecticide design and biocontrol measures, advancing eco-friendly mosquito management strategies.

Devasena *et al.* highlighted sustainable biofuel production from fruit waste, offering a waste-to-energy approach. Their work underscored the dual benefit of reducing organic waste accumulation and providing renewable energy alternatives to fossil fuels. Krishanan *et al.* quantified airborne microbial loads in clinical and adjacent environments. Their study demonstrated the importance of microbial monitoring for infection control and prevention, contributing to improved healthcare facility management. Krishanan *et al.* studied the effect of aquarium wastewater irrigation on mustard and green gram plants. Results indicated enhanced growth responses, suggesting the feasibility of using treated wastewater in agriculture as a resource recovery and sustainability measure. Krishanan *et al.* explored the green synthesis of superparamagnetic iron oxide nanoparticles (SPIONs). Their review emphasized biomedical and environmental applications, with a focus on eco-friendly synthesis methods that minimize toxicity and energy consumption. Geetha *et al.* discussed fabrication and analysis of nickel

oxide nanoparticles for advanced applications. Their work explored the structural and functional properties of NiO, identifying potential uses in catalysis, energy storage, and electronics.

Sindhuja *et al.* synthesized and characterized spinel SrFe₂O₄ nanoparticles. Their review highlighted the application potential in magnetic storage, catalysis, and biomedical fields, demonstrating how nanostructuring enhances material properties. Geetha *et al.* reported on the microwave-assisted synthesis and characterization of ZnO nanoparticles. Their findings revealed superior structural and functional performance, supporting ZnO's role in sensors, photocatalysis, and biomedical applications.

MATERIALS AND METHODS

Plants such as *Ocimum sanctum*, *Leucas aspera*, and *Tridax procumbens* were selected based on traditional usage and prior literature. Leaves and other plant parts were dried, powdered, and subjected to solvent extraction using methanol, ethanol, hexane, or water, depending on the polarity of desired compounds. The concentrated extracts were diluted into working concentrations (typically 50–500 ppm) to prepare larvicidal solutions. Fourth instar larvae of *Aedes aegypti*, *Anopheles stephensi*, and *Culex quinquefasciatus* were collected and acclimated under laboratory conditions. Larvae were exposed to each test solution in replicates. Controls (solvent only) were maintained in parallel. Mortality was recorded after 24 and 48 hours of exposure. Dead larvae were confirmed by absence of movement even after probing.



Figure 2. Process of Pest Management.

LC₅₀ and LC₉₀ values were calculated using probit analysis. One-way ANOVA was performed to compare mortality among treatment groups.

RESULTS AND DISCUSSION

The larvicidal efficacy of five medicinal plant extracts was evaluated against three major mosquito vectors—*Aedes aegypti*, *Anopheles stephensi*, and *Culex quinquefasciatus*. The results are presented below in terms of LC₅₀ and LC₉₀

values (ppm), which represent the concentration required to kill 50% and 90% of larvae, respectively. The variation in larvicidal efficacy across species is attributed to differences in the phytochemical composition of each plant. Essential oils rich in eugenol and menthol (e.g., in *Ocimum sanctum* and *Mentha arvensis*) have shown strong neurotoxic effects on mosquito larvae. In contrast, the lower efficacy of *Hyptis suaveolens* could be due to less potent secondary metabolites or lower extract concentration.

Table 1. Comparison between Lethal concentration.

Plant Extract	Target Mosquito	LC ₅₀ (ppm)	LC ₉₀ (ppm)
<i>Ocimum sanctum</i>	<i>Aedes aegypti</i>	68.4	132.5
<i>Leucas aspera</i>	<i>Anopheles stephensi</i>	52.1	110.4
<i>Tridax procumbens</i>	<i>Culex quinquefasciatus</i>	75.3	143.8
<i>Mentha arvensis</i>	<i>Aedes aegypti</i>	61.7	124.6
<i>Hyptis suaveolens</i>	<i>Culex quinquefasciatus</i>	79.2	151.7

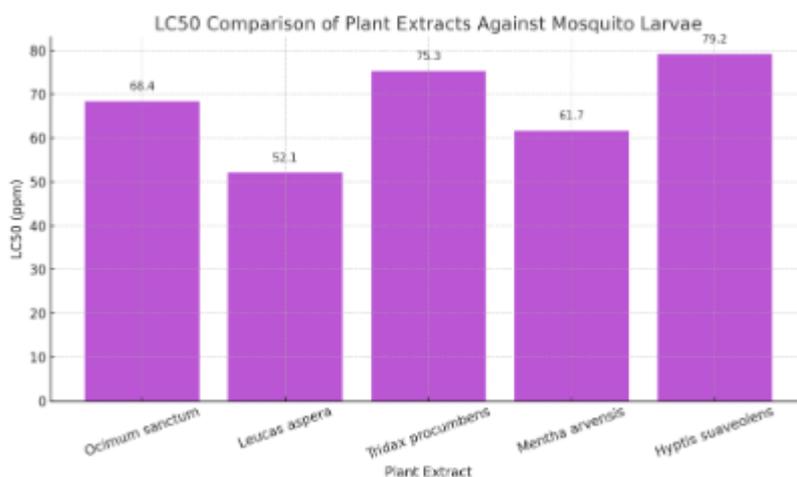


Figure 3. Comparison Graph.

CONCLUSION

Medicinal plants offer a promising, eco-friendly alternative to synthetic insecticides for the control of mosquito vectors responsible for transmitting critical public health diseases. A wide array of botanicals including *Leucas aspera*, *Tridax procumbens*, *Ocimum sanctum*, *Hyptis suaveolens*, and *Mentha arvensis* demonstrate significant larvicidal and repellent properties against major mosquito species. Their phytochemical constituents act through multiple mechanisms, offering a multi-targeted approach to vector suppression. Despite the growing body of supportive research, challenges such as low compound stability, lack of standardization in extraction and formulation methods, and limited field validation remain. Bridging traditional ethnobotanical knowledge with modern scientific methodologies including nanotechnology, molecular assays, and standardized bioefficacy testing will be

essential to unlocking the full potential of plant-based mosquito control. Future interdisciplinary collaborations and regulatory support are key to translating these phytochemical solutions from laboratory research into practical, scalable, and sustainable public health tools. Nanotechnology Integration: Development of nanopesticides for improved delivery, stability, and target specificity. Synergistic Formulations: Combining phytochemicals with microbial agents (e.g., *Bacillus thuringiensis*) or synthetic agents to enhance efficacy. Field Validation: Conducting controlled trials to assess real-world performance and environmental impact. Standardization Protocols: Establishing quality control norms for extraction, dosage, and storage. Ethnobotanical Conservation: Encouraging sustainable harvesting and protection of medicinal plant biodiversity.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest

ETHICS APPROVAL

Not applicable

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AI TOOL DECLARATION

The authors declares that no AI and related tools are used to write the scientific content of this manuscript.

DATA AVAILABILITY

Data will be available on request

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