

A review on mosquito repellent properties of Neem, Eucalyptus and Citronella

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Abstract - Mosquito-borne diseases like malaria, dengue fever, Zika virus, and chikungunya is major public health problem around the world, especially in tropical and subtropical regions like Southeast Asia, Africa, and Latin America. Controlling mosquito vectors is one of the main ways to prevent and cure these diseases. Although synthetic insecticides are widely used for mosquito control, there are growing concerns about their impact on the environment, the rise of insecticide resistance, and their harmful effects on human health and other organisms. Because of this, there is need of alternative method such as traditional methods that involve herbal plants. Medicinal plants have been used in traditional medicine for many years, with many known for their ability to repel insects. These herbal plants contain a wide range of natural chemicals, including essential oils, alkaloids, terpenoids, and flavonoids, which help keep mosquitoes away. In this chapter we gives information about mosquito repellent properties of herbal plants like eucalyptus, neem and citronella and how they work as mosquito repellents.

Index Terms - Mosquito repellent, Neem, Eucalyptus, Citronella.

I. INTRODUCTION

A. Overview of mosquito-borne diseases

Mosquitoes are insects that carry diseases and spread different types of harmful pathogens to healthy people through their bites. Tropical and subtropical regions like Southeast Asia, Africa, and Latin America have higher rates of mosquito-borne diseases. These insects reproduce quickly in warm and humid climates, and their population often changes with the seasons. The favorable weather conditions during certain times of the year lead to more mosquito activity and increase the chances of disease outbreaks. [1]

Mosquito-borne diseases such as malaria, dengue, Zika, and chikungunya continue to threaten public health, especially in tropical regions. Although synthetic insecticides are commonly used for control, their environmental impact, health risks, and rising resistance have prompted interest in natural alternatives. Medicinal plants, containing bioactive compounds like essential oils, alkaloids, terpenoids, and flavonoids, offer a safer and eco-friendly option for mosquito repellent and vector control. [2]

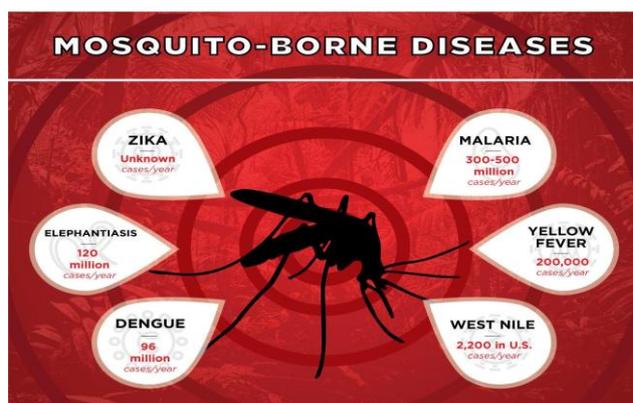


Fig. 1. Mosquito-Borne Diseases [2]

Diseases	Germ that causes	Mosquito types (Vector)	Who It affects (Hosts)
Malaria	Plasmodium parasites	Female Anopheles mosquito	Humans
Dengue	Dengue virus (Arbovirus)	<i>Aedes aegypti</i>	Humans
Zika	Zika virus	<i>Aedes aegypti</i> , <i>Aedes albopictus</i>	Humans, monkeys
Chikungunya	Chikungunya virus	<i>Aedes aegypti</i> , <i>Aedes albopictus</i>	Humans
Yellow Fever	Yellow fever virus	<i>Aedes aegypti</i> , <i>Haemagogus</i> , <i>Sabethes</i> mosquitoes	Humans, monkeys
West Nile Virus	West Nile virus	<i>Culex pipiens</i> , <i>Culex tarsalis</i>	Birds (main), humans and horses (sometimes)
Japanese Encephalitis	Japanese encephalitis virus	<i>Culex tritaeniorhynchus</i>	Humans, pigs and birds
Lymphatic Filariasis	<i>Wuchereriabancrofti</i> , <i>Brugia</i> species	<i>Culex</i> , <i>Anopheles</i> , <i>Aedes</i> mosquitoes	Humans
Rift valley Fever	Rift Valley virus	<i>Culex</i> , <i>Anopheles</i> , <i>Aedes</i> mosquitoes	Animals (main), humans (sometimes)

Table 1. Disease and affecting Mosquitos

B. Mosquito bite process mechanism [3]

The pathophysiology of itch in mosquito bites is not well understood, but **3 mechanisms** have been found these mechanisms are based on the assumption that mosquito salivary components.

1) First Mechanism :

- First mechanism involves direct induction of itch utilizing classic pruritic pathways, the second is an IgE-mediated hypersensitivity reaction, and in the third, salivary antigens modulate the hosts immune response.
- Histamine elicits itch by binding to histamine-specific receptors located on sensitive nerve endings in the skin.

2) Second Mechanism :

- Second mechanism may involve the onset of an IgE-mediated hypersensitivity reaction in response to salivary components.
- IgE-mediated activation of mast cells at the site of the bite causes the release of a number of mediators, including histamine, tryptase, cytokines, and eicosanoids (such as leukotrienes), all of which may play a central role in the development of itch.
- Histamine causes itch via mechanisms stated previously.
- Kuraishi and colleagues suggested that 5-lipoxygenase metabolites other than leukotriene (LT) B₄ and cysteinyl leukotrienes (LTC₄, LTD₄, and LTE₄) may be involved in mosquito bite-induced itch.
- This conclusion was made due to the observation that the 5-lipoxygenase inhibitor zileuton suppressed scratching in a murine model after an intradermal injection of mosquito salivary gland extract.
- In contrast, a leukotriene B₄ antagonist, the cysteinyl LT antagonist pranlukast, and the LTD₄ antagonist MK-571 did not suppress scratching.

3) Third Mechanism :

- The third mechanism, salivary components may modulate an IgE-independent inflammatory response.
- This modulation may involve direct mast cell degranulation and/or stimulated skewing to a Th₂ delayed hypersensitivity response.
- *Anopheles stephensi* (Lis.) degranulation in vitro led to the release of different mediators including histamine and tryptase, both of which are involved in the itch pathway.
- Salivary components may also modulate the immune system by shifting host immune responses to a Th₂ phenotype.

- It has been demonstrated that certain mosquito saliva components, in particular sialokinin and SAAG-4, tend to alter host immune responses away from a Th1 phenotype and towards a Th2 phenotype in mice.
- This is reflected by the decrement of expression of IFN- γ and the rise of interleukin (IL)-4 in murine models.
- The Th2 switch determines the release of cytokines such as IL-4, IL-5 and IL-13 and IL-31, which have been previously implicated in the pruritic pathway of Th2 delayed hypersensitivity response pathway.

C. *Need of mosquito repellent*

According to the World Health Organization (WHO), vectorborne diseases account for more than 17% of all infectious diseases worldwide and cause over 700,000 deaths every year. Among these, mosquitoes are the most dangerous vectors responsible for transmitting malaria, dengue, chikungunya, Zika virus, yellow fever, and lymphatic filariasis.

Dengue is a mosquito-borne viral infection. Roughly half of the world's population are now at risk. There is no specific medicine to treat dengue; therefore, the prevention of mosquito bites remains a key strategy. These diseases are widespread in tropical and subtropical regions, including India, and continue to pose a major threat to public health despite large-scale control programs. Many of these diseases are preventable through protective measures and community mobilization.

The WHO emphasizes that preventing mosquito bites is one of the most effective and simple strategies to reduce disease transmission. While measures such as insecticide-treated nets and indoor residual spraying are useful, personal protection using mosquito repellents (creams, oils, or vaporizers) remains an important first-line defense, especially in areas with outdoor exposure or insecticide resistance.

II. REVIEW OF LITERATURE

A. *Significance of natural mosquito repellent* [5]

Many mosquito repellents are available today that work well, but most contain a harmful chemical called DEET, which can be bad for health. Repellents made from essential oils may not last long because the oils evaporate quickly, so they need to be applied more often. These cannot always be used directly on the skin, as they may cause rashes or irritation.

Plant-based mosquito repellents have been used for generations in traditional practices as a way to protect people from Anopheles mosquitoes. The knowledge of these traditional repellent plants is very useful today for developing new natural repellents that can be safer alternatives to chemical repellents.

Even though DEET-based products are widely used, some researchers such as Tenenbein and poison control centers that have reported only a few cases of skin allergies, reactions, or more serious issues like seizures and heart problems after using or accidentally swallowing high amounts of DEET, especially in children and adults.

B. *Repellent action mechanism* [6]

1. Olfactory Disruption
 - Interferes with an insect's sense of smell.
 - May mask the host's scent, making it harder for insects to locate a food source.
 - Some repellents activate competing olfactory pathways, confusing the insect's ability to recognize human odors
 - Example : CO₂, lactic acid, sweat compounds).
2. Sensory Interference
 - Affects other sensory modalities such as taste or touch.
 - Some repellents activate taste receptors that trigger a "don't eat" response.
 - Others create a physical barrier or irritant effect on the insect cuticle or antennae, discouraging landing and feeding.
3. Behavioral Disruption
 - Alters an insect's normal behavioral patterns.
 - May cause insects to move away from the repellent source.
 - Can interfere with their search behavior for hosts or breeding sites.
 - In some cases, repellents induce behaviors incompatible with feeding or mating, reducing transmission risk.
4. Concentration Dependent Effects
 - The effectiveness of a repellent depends on its concentration.
 - At low concentrations, certain compounds may even be attractive to insects.
 - At higher concentrations, they become repulsive.
 - This is because repellents interact with different sensory pathways/receptors at different concentration levels.
 - Example: Many natural repellents (citronella, neem, clove oil) work via a combination of olfactory masking + contact irritant effects.

C. Profile of herbs

1. Citronella

The scientific name of the citronella is *Cymbopogon nardus* which is widely known as citronella grass. It is an aromatic, long lived grass species classified under the Poaceae family [7]. The essential oil of *Cymbopogon nardus* (citronella) is typically extracted through the Clevenger-type hydrodistillation method. The plant serves as a primary source of citronella oil, an essential oil recognized for its mosquito repellent efficacy. This oil is typically obtained through steam distillation of the aerial portions of the grass.[8]

Citronella oil primarily contains the monoterpene aldehyde citronellal, along with its oxidation product citronellol and geraniol. These compounds exhibit strong insect-repellent activity.[9]



Fig. 2. Citronella

Citronella, obtained from *Cymbopogon* species, is widely recognized as a natural mosquito repellent. Its repellent activity, however, is limited due to the rapid evaporation of its volatile constituents, generally providing protection for less than 2 hours [10]. Citronella derived from lemongrass demonstrated 100% repellency against *Anopheles culicifacies* for up to 11 hours. The effectiveness of citronella-based products has been demonstrated against *Aedes*, *Anopheles*, and *Culex* mosquitoes, with repellency commonly evaluated through cage and room assay methods. In room method studies, citronella oil alone or in combination with vanillin achieved complete repellency for a duration of at least 3 hours. [11]

2. Neem

Azadirachta indica, commonly referred to as neem, margosa, nimtree, or Indian lilac, is a member of the mahogany family (Meliaceae) and one of the two species within the genus *Azadirachta*.¹² Neem (*Azadirachta indica*) is a fast-growing evergreen tree, typically reaching heights of 12–24 m, and is widely distributed across tropical and subtropical regions, including semi-arid and wet-tropical areas.¹³ The tree's fruits and seeds serve as the primary sources of neem oil. [12]

The principal bioactive constituents of neem oil are limonoids, including azadirachtin A, nimbin, and salannin, which are largely responsible for its insecticidal and repellent properties [13]. Neem seeds contain approximately 200 phytochemicals, with limonoids receiving particular attention due to their bioactivity. Oil extracted from the seed kernels, commercially known as neem oil or margosa oil, is widely employed as a natural insect repellent and pesticide. [14]



Fig. 3. Neem seeds and leaves

Neem seed kernels are the richest source of bioactive compounds. These are mainly extracted from kernels and press cake using water, hexane, pentane, or alcohol. Although only slightly watersoluble, they dissolve well in organic solvents, and extraction can be done using simple or industrial methods [15]. Azadirachtin, one of the first bioactive compounds isolated from neem, is considered the principal agent responsible for its insecticidal activity, accounting for approximately 90% of its effect against many pests. Rather than causing immediate mortality, azadirachtin primarily acts by repelling insects and interfering with their growth and reproductive processes.[16]

EUCALYPTUS

Eucalyptus is a diverse genus comprising over 700 species of flowering plants belonging to the family Myrtaceae. The majority of these species are medium to tall trees, with some occurring as mallees (multi-stemmed growth forms) and a few as shrubs.¹⁶



3. Eucalyptus

Eucalyptus essential oil is obtained by drying, crushing, and distilling the leaves, and the concentrated extract is typically diluted before use in alternative or complementary therapies [17]. Chemically, eucalyptus oil is a diverse blend of terpenes and aromatic derivatives, including monoterpenes, sesquiterpenes, and compounds such as phenols, oxides, esters, alcohols, aldehydes, and ketones. [18]

Essential oils demonstrated notable repellency against the malaria vector *An. Stephensi*. A combination of 10% *Eucalyptus globulus* oil with 1% *Syzygium aromaticum* oil showed superior efficacy compared to other mixtures or individual oils, indicating its potential as an effective mosquito repellent. [19]

Plant Oil	Plant Name	Plant Part Used	Main Compounds	Repellency (%)	Protection Time (hrs)
Citronella	<i>Cymbopogon nardus</i> , <i>winterianus</i>	C. Leaf	Citronellal, Geraniol, Citronellol	100	11
Lemon Eucalyptus	<i>Eucalyptus citriodora</i>	Leaf, Twig	Citronellal, Citronellol	52.4	8
Eucalyptus	<i>Eucalyptus dives</i>	Leaf	Cineole, Terpineol, Citronellol	28.6	5.5
Neem	<i>Azadirachta indica</i>	Leaf, seed	Azadirachtin, Nimbin	70-100	2-5

Table 2. Plant-Based Mosquito Repellents

III. EVALUATION OF MOSQUITO REPELLENT

1. Arm-in-Cage Test (AIC)

- WHO Standard Method: Measures the repellent efficacy of topical repellents (e.g., creams, sprays, lotions) on human skin. A human volunteer applies the repellent on a forearm.
- The arm is then inserted into a cage containing a specific number of mosquitoes. Biting attempts or landings are recorded over a set time. [20]

2. Tube Test (WHO Cone Bioassay)

- Used for evaluating insecticide-treated materials like bed nets or clothing. Mosquitoes are exposed to the treated surface for a fixed period (usually 3 minutes). Knockdown and mortality are recorded after 60 minutes and 24 hours. [21]

3. Field Cage or Semi-Field Test (Large Enclosures)

- Evaluates spatial repellents like coils, vaporizers, or area sprays in a controlled but semi-natural environment. A large enclosure is set up with volunteers and free-flying mosquitoes. The repellent product is placed in the environment. Human landing counts or mosquito behaviour (attraction vs. avoidance) is monitored. [22]

4. Field Trials (Open Field Study)

- Real-world evaluation of repellents under natural conditions. Volunteers use the repellent in areas with natural mosquito populations. Mosquito landings and bites are counted (e.g., using Human Landing Catch method). [23]

5. Olfactometer Test (Y-Tube or Wind Tunnel)

- Tests mosquito behavioural response to repellent volatiles in a controlled airflow setup. A mosquito is released in a Y-shaped or tunnel device. One arm contains the repellent Odor; the other is a control. The mosquito's directional choice is recorded. [24]

6. Contact Irritancy and Excito-repellency Assay

- Evaluates both contact irritancy (mosquitoes leaving after landing) and non-contact repellency (mosquitoes deterred without touching).
- Mosquitoes are exposed to treated surfaces or volatile repellents. [25]

7. Knock down and Mortality Tests (For spatial insecticidal repellents)

- Measures the toxic effects of vapours or treated surfaces. Mosquitoes are exposed to vapours or surfaces in chambers. Knockdown is recorded at set intervals (e.g., 60 min), and mortality at 24 hours. [26]

8. Chemical Analysis (GC-MS, HPLC)

- Measures the persistence of the active ingredient on skin or surface over time. Swabs are collected from treated surfaces/skin and analysed. [27]

IV. FUTURE PROSPECTS

A. Possible formulations

1. Mosquito repellent gel -

Globally, the tropical and sub-tropical regions are primarily affected by vector-borne diseases. Mosquito is the sole vector for the transmission of malaria, dengue, and chikungunya which transmits more than 750 million people every year. Nearly 3 million lost their life annually, of which nearly 90% of the mortality lies in infants. Currently, for the prevention of mosquito-borne diseases, the control of mosquito larval growth and personal protection from mosquito bites by the use of mosquito nets and mosquito repellent remained the chief methods. Scientific innovations include mosquito vaccines, but it is still at a nascent level and is not yet recommended for human use. [28]

2. Laundry detergent-

Mosquitoes are among the most disturbing blood sucking insects afflicting human beings. Several mosquito species belonging to genera Anopheles, Culex and Aedes are vectors for the pathogens of various diseases like Dengue fever, Malaria, Yellow fever, Japanese Encephalitis and several other infections. The control of mosquitoes is an important public health concern around the world. As most of the mosquito repellent products and devices available in the market are reported to have harmful effects on human beings, the objective of the present study is to develop effective plant-based mosquito repellent product. [29]

3. Sample lotion -

Head lice (*Pediculus humans capitis*) are considered as the most prevalent parasitic infestation of humans in the developed and developing countries, where the parasitic insects live on the scalp and neck hairs of humans and feed on human blood, causing social distress, discomfort, anxiety, and embarrassment. There are many products on the markets formulated as creams, shampoos or lotions based- insecticides with different pharmacological mode of actions to control ectoparasites on humans such as lice and mites. [30]

4. Sanitizer-

It is supposed that a solicitous innovation solves many difficulties all at once. Automation and technology have different functions, and less human collaboration is required. Automation is the main idea, and one main problem that all go through is problems related to health. With reference to the present scenario of the pandemic, innovation proves to be quite beneficial. There has been a loss of lives due to diseases like Malaria, which can be prevented. [31]

5. Shampoo-

Head louse *Pediculus humanus capitis* De Geer (Pediculidae: Phthiraptera) is a small and wingless insect with the body size of 2.5-4.5 mm. It is an ectoparasitic insect that feeds only on human blood more than three times per day. The most common symptoms of head lice infestation are red spots, irritation, pruritus of the scalp, and the secondary symptoms are sleep loss, blood loss, anemia and psychological distress. Moreover, adverse effects of chemical pediculicides such as irritation and burning sensation to the scalp, ataxia, tremor and seizure have been noted. Presently, there are considerable concerns about chemical pediculicides related to human health, long chemical persistence in the environment, food supply, water, and air. [32]

V. DISCUSSION

A. *Benefits of herbal formulations*

- Free from synthetic chemicals: the herbal formulations and herbal products are derived from natural plant sources and are often free from harsh synthetic additives. Being natural and obtained from plant source, they tend to align more closely with the body's biology, reducing the risk of adverse reactions.
- These herbal formulations tend to have very less side effects as compared to synthetic drugs, herbal products generally have fewer and milder side effects. Many herbs contain a combination of bioactive compounds that work synergistically. Unlike single compound synthetic drugs, these multi-compound mixtures may balance each other out, reducing the risk of strong or sudden side effects [33] [34] [35].
- The toxicity level of these drugs are also low compared to synthetic products. Compared to synthetic drugs, which are highly concentrated and target-specific, herbs are sometimes considered to be less likely to cause acute toxicity [35].
- The herbs like Ashwagandha and Tulsi help the body adapt to stress and strengthen immunity. They also having antioxidant properties, many herbs are rich in antioxidants that protect against oxidative stress and cellular damage.
- Herbal medicine often targets the underlying cause of illness rather than just the symptoms. Ayurveda and Traditional Chinese Medicine, herbs are used to restore balance among bodily systems.
- Sustainable and eco-friendly and renewable sources: Herbs are usually cultivated and harvested sustainably they have less environmental impact, production of herbal medicines typically results in less chemical waste [33] [34].
- Herbal products are generally more affordable than modern pharmaceuticals and can be made easily available from cultivation.

B. *Side effects of herbal products*

- Herbal medicines, though perceived as natural and safe, can cause adverse effects ranging from mild gastrointestinal or skin reactions to serious organ damage such as hepatotoxicity, nephrotoxicity, and cardiotoxicity. [37] [38]

- Severe cases have been linked to herbs like Kava, Comfrey, and Aristolochia, and products such as Hydroxycut. [36]
- Risks also arise from drug–herb interactions, contamination with heavy metals or undeclared drugs, and overdose. [36] [37]
- Elderly, pregnant women, and patients with chronic diseases are particularly vulnerable to such adverse effects. [38]

VI. CONCLUSION

Herbal mosquito repellents derived from plants like neem, citronella, eucalyptus, and lemongrass offer safe, eco-friendly alternatives to chemical repellents. They provide effective protection against major mosquito species while also offering antimicrobial and skin-friendly benefits. Standardization and safety assessment are essential to ensure efficacy, making plant-based repellents a sustainable and cost-effective option for vector control.

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