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Review Article

# Repellent Activity of Plant Extracts, Essential Oils and their Combinations against Different Mosquito Species: A Review

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**ABSTRACT**

Mosquitoes are majorly responsible for causing vector-borne diseases such as malaria, filariasis, chikungunya, dengue, zika, yellow fever, west nile etc. *Aedes, Anopheles, Culex* are the main genera among other mosquitoes' species, that are affecting human beings with such dreadful diseases worldwide. To control the transmission of diseases by mosquitoes generally mosquito nets, ITNs and LLINs, DDT, DEET, IR3535 are being used. Prolong use of these harmful chemicals not only cause development of resistance in mosquitoes but also have shown adverse effects on humans as well as on environment. So, there is a growing urge/need of finding a suitable mosquito repellent from natural origin, that have potential to prevent such vector-borne diseases with least side- effects on humans as well as on environment. In this review, we have enlisted various Essential oils (EO) that are having mosquito repellent properties and some of them such as *Cymbopogon nardus, Eucalyptus maculata, Cymbopogon excavatus, Mentha piperita, Azadirachta indica* are already used in various mosquito repellent formulations that are being marketed presently. EO of particular plant can be extracted from respective parts of it such as seeds, roots, rhizomes, stems, leaves, bracts, fruits, bark and inflorescences mainly by hydrodistillation and steam distillation. Gas chromatography coupled to mass spectrometry (GC-MS) is the identification technique used for identification of EO constituents. In addition, the combinations of potent EOs are also found to be the best effective way to be used as mosquito repellent so that repellent potential enhanced due to synergism as well as negates the harmful effects of individual oils. The efficiency of essential oils as well as its protection time can also be enhanced by using vanillin and formulation techniques like microencapsulation and nanoemulsion. Based on market coverage as well as economical cost, synthetic repellents are frequently marketed than essential oils but these EOs, extracts or natural products have the potential to provide efficient and safer repellents for humans as well as the environment.

**Keywords:** Herbal mosquito repellent, Essential oils combinations, Natural products, *Anopheles stephensi, Aedes aegypti,* Dengue, Malaria.

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## INTRODUCTION

According to World Health Organisation Report 2017, Seventy Lakh people died due to diseases caused by vectors. Mosquitoes are the prominent vectors for spreading of vector-borne diseases like malaria, filariasis, chikungunya, dengue, zika, yellow fever, west nile etc. The most dreadful genus is of *Anopheles, Culex*, and *Aedes*, which belong to Culicidae family.[1] Out of all the contagious diseases occurred worldwide, 17 % are caused by mosquitoes only.[2] Anopheles is a primary vector of malaria whereas *Aedes albopictus* act as secondary vector for diseases like dengue and chikungunia. These vectors require blood of host for production of their eggs and in process of sucking blood from infected host, they pass on the diseases to the healthy host and ultimately leads to dissemination of dreadful diseases. The chemical and microbial secretions from host`s skin, the carbon dioxide from the exhaled air, urine, body heat, odour and moisture are the main factors which are responsible for proneness of host towards mosquito.[3] *Bacillus cereus, Bacillus subtilis, Brevibacterium epidermidis, Corynebacterium minutissimum, Staphylococcus epidermidis* are those bacterial species whose population is high in mosquito prone individual as well as the degrading volatile products of the sweat by them also enhances attractiveness of mosquitoes towards the host.[4] L-Lactic acid, carboxylic acid mixtures, $NH_3$ and other secretions from the sweat act as an attractant for mosquitoes.[3] On the other hand, the carbon dioxide released in exhaled air shows synergistic effect with the body secretions that make body odour for attracting and orienting mosquitoes towards host.[5] To control the transmission of diseases by mosquitoes generally mosquito nets, ITNs and LLINs are used. But to overcome the restriction caused by mosquito nets, mosquito control by chemicals such as DDT, DEET, IR3535 in the form of IRS, Peridomestic space spraying is being done. After having so many advantages, DEET has many drawbacks just like disagreeable odour, numbness of lips as side effects as well as occurrence of resistance in mosquitoes against DEET and also causes damage to the surfaces or fabrics on which it is applied. Permethrin has efficacy against wider range of insects like mosquitoes, ticks, tsetse flies, fleas, lice etc. but longer use of higher concentrations of permethrin caused tremors, unorganised coordination, paralysis, rise in body temperature, skin and eye irritation as well as affects immune system also. Picaridin and DEPA must be avoided in breast-feeding or

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pregnancy. IR3535 must not be used in malaria endemic areas.[6] These chemicals develop resistance in various mosquitoes and causes harmful effects on humans as well as on environment too when longer used which emerges the need of mosquito repellent from natural origin so that it will become possible for prevention of diseases caused by mosquito without adversely affecting the environment. It is well established from the literature survey that various EOs have shown potential to be used as mosquito repellent and some of the EOs such as *Cymbopogon nardus, Eucalyptus maculata, Cymbopogon excavatus, Mentha piperita, Azadirachta indica* are used in commercial anti-mosquito formulations presently as well. There are problems associated with usage of individual EOs also because after having proven repellent potency against mosquitoes, some EO has pungent odour while other has skin and eye irritant property which make either of the EO unbearable if used in mosquito repellent formulations. And if individual EO does not have such unwanted properties which affect the humans, some require higher Repellent doses (RD50) to repel mosquitoes or some have capability to restrain only specific mosquito species.[7,8] The combinations of potent EOs are also found to new approach to be used as mosquito repellent so that repellent potential enhanced due to synergism as well as one EO is able to mask or negates the unwanted property of another EO used in combination. There is also benefit to use combination over individual oil because combination will be able to show repellency against all the selected species of mosquito not only against specific species as in case of some individual EOs. Apart from this, formulating these extracts, EOs or their combinations in various preparations like creams, sprays, ointments, polymer mixtures, or microcapsules provide controlled release and also enhances the effective repellenct time of respective EOs or extract.[9]

## Bioassays for Mosquito Repellent Activity

Various bioassays are enlisted in WHO 2013[10] and 2009[11] guidelines but still there is need for more appropriate bioassay for mosquito repellency. Researchers use various methods to assess the repellency of essential oils/ compounds against mosquitoes. The most used method for testing EOs, is the arm-in-cage assay. It was published in 1919 and it is likely the first well planned laboratory test of mosquito repellency.[12] Quantities of EO were previously dissolved in a fixed solvent volume and applied uniformly on the arm (from wrist to elbow) of a volunteer, whereas the other arm is treated with the solvent. The subject inserts his or her product-treated arm and the control in independent cages with a fixed number of blood unfed female mosquitoes. The time elapsed until the first bite in the treated arm is recorded and presented as PT, the number of mosquitoes biting in a determined time may also be recorded in order to calculate the percentage of repellency. Taking into account the quantity of EO applied and the area of the subject's arm, the dosage is calculated in $\mu L/mm^2$ but difficulty in counting the number of mosquitos landing on the skin or bloodsucking accurately is the limitation of this assay.[13] The repellent activities are presented in values of RD50 and RD95 (calculated statistically), representing the dosage of EO capable to repel the 50% and 95%, respectively of the insect population. A similar method has been developed by using the depilated abdomen of a white mouse, instead of a human arm.[9,14]

Repellency was evaluated using Mosquito Repellency Bioassay. Aliquot (500 microliter) of the test solution of the oils or their combinations was dispensed separately over a cardboard sheet of size (22*35 mm) and thickness (2.5 mm) equal to commercially available mosquito mats. Twenty adult mosquitoes were taken for the experiment and the observation of repellency studies was done by counting the migrated mosquitoes at an interval of 15 min for a total period of 1hr for assessment of true repellency and percentage repellency (PR) was calculated after 1hr experimental duration.[15] The Y-tube olfactometer bioassay has also been used for testing repellency, it consists on a glass Y-tube with a main arm (the stem) and two arms containing one repellent and the control in other one, where a low rate air movement is created by sucking the air in the two arms of the Y-tube with a pump connected to the stem. The essential oil sample and control are applied on a paper attached to the arms of the tube. Insects are introduced into the tube by a hole located at the centre (the joint point of the three tubes), after introduction the hole is closed with a rubber stopper and the pump is operated. After seconds of exposition, the number of insects on each of the two tubes (treated and control) are scored to assess the percentage repellency.[9,16] K&D bioassay system that determines the biting deterrence was developed for high throughput screening of compounds. In the room method, various body parts including feet, legs and arms of the test subject are treated with the desired chemical. The subject then walks into the mosquito-filled room or sits outside in case of open area testing. Number of mosquitoes landing on the treated parts of the body were collected with an aspirator at various time intervals after treatment to determine the repellency and protection time of various products. All the bioassay systems use positive control, commonly DEET and a negative control (solvent).[17] It is a common conclusion that the results of one bioassay don't compare with the other system at the same concentration of the material.

## Essential oils (EOs), plant extracts as Natural Mosquito Repellents

Several plant species indigenous to India had been evaluated for their mosquito repellent potential, are also being enlisted in Table 1. Govindarajan *et al*., (2016) reported that essential oil (EO) of leaves of *Origanum scabrum* had shown both larvicidal and repellent activity against four of the mosquito species and its maximum protection period against *Anopheles stephensi, Aedes aegypti, Culex quinquefasciatus*, *C. tritaeniorhynchus* are 210 min, 180 min, 150 min, 120 min. Mathew, (2016) noted down mosquito repellent activity of 20% EO in ethanol of *Plectranthus amboinicus* leaves against *Aedes aegypti* with maximum protection period was six hours.[19] Champakaew *et al*., (2015) observed that *Angelica sinensis* hexane extract have shown maximum protection period of 7.5 hours against *Aedes aegypti*.[20] Nasir et al., (2015) reported repellent activities of *Azadirachta indica* leaves EO against *Aedes aegypti* and *Aedes albopictus* with protection period of 246 min and 256 min.[21] Peter and Mwangi, (2014) validated that *Azadirachta indica* EO had shown consistent repellency of 85.79% from concentration from 5% to 10%.[22] Govindarajan and Sivakumar, (2015) illustrated that methanolic extract of *Erythrina indica* leaves had shown best repellent activity against *Anopheles stephensi, Aedes aegypti, Culex quinquefasciatus* with maximum protection period of 210 min, 210 min and 180 min.[23] Phukerd and Soonwera, (2014) noted that 10% concentration of *Citrus hystrix* peel EO had shown repellency against *Aedes aegypti* and *Culex quinquefasciatus* with protection period of 75 min and 11 min.[24] Tawatsin *et al*., (2001) reported the mosquito repellent activity of 25% EO of *Citrus hystrix* leaves with maximum protection periods of 3 hr, 1.5 hr, 2.5 hr ( with 5% vanillin) and 1 hr, 0.5 hr, 0.5 hr (without vanillin) against *Aedes aegypti, Anopheles dirus* and *Culex quinquefasciatus*.[25] Govindarajan and Sivakumar, (2015) observed the repellent activity of *Asparagus racemosus* root extract against *Anopheles stephensi, Aedes aegypti, Culex quinquefasciatus* with protection periods of 180 min, 180 min and 150 min.[23] Kumar *et al*., (2014) reported that *Apium graveolens* seed oil had both larvicidal and repellent activity against *Aedes aegypti* mosquito species with protection period of 150 min.[26] Kulkarni and Pawar, (2013) noted down that *Lavandula gibsoni* EO have shown repellent activity against *Aedes aegypti* with maximum protection period of 7 hr 25 min while its major constituents α-terpinolene and

thymol in a ratio of 2:1 gave synergistic effect for a period of 370 min which is higher than their individual protection periods against *Aedes aegypti* mosquito.[27] Conti *et al*., (2021) reported that EO of *Hyptis suaveolens* fresh leaves had both larvicidal and repellent activity against *Aedes albopictus* with maximum protection period of 134.8 min.[28] Govindarajan and Sivakumar, (2012) observed that methanolic extract of *Andrographis paniculata* had shown repellency with protection periods of 210 min and 180 min against *Culex quinquefasciatus* and *Aedes aegypti*.[29] Tawatsin *et al*., (2006) reported the repellent activity of EO of *Hedychium coronarium* against *Aedes aegypti, Aedes albopictus, Anopheles dirus* and *Culex quinquefasciatus* with protection periods of 0.9 hr, 8 hr, 8 hr and 7.5 hr in one minute exposure time.[30] Prajapati *et al*., (2005) illustrated that EO of *Cinnamomum zeylanicum* leaves had both larvicidal and repellent activity against *Anopheles stephensi, Aedes aegypti, Culex quinquefasciatus* with respective repellent dose 50 ($RD_{50}$) were 23 mg/mat, 28.4 mg/mat and 20.6 mg/mat in one hour.[30] Tawatsin *et al*., (2001) reported the mosquito repellent activity of 25% EOs of *Cymbopogon winterianus* and *Ocimum americanum* with maximum protection periods of each of the oil was 6.5 hr, 8 hr, 8 hr ( with 5% vanillin) and 3 hr, 4 hr, 8 hr (without vanillin) against *Aedes aegypti, Anopheles dirus* and *Culex quinquefasciatus*.[25]

Specifically focusing on the plant species that are found in North-Indian region narrows down screening to following plant species. Mathew, (2016) noted down the mosquito repellent activity of 20% EO in ethanol of *Ocimum sanctum* leaves against *Aedes aegypti* with maximum protection period was six hours.[19] Gokulakrishnan *et al*., (2013) reported that *Pogostemon cablin* leaves EO had shown repellency against *Anopheles stephensi, Aedes aegypti, Culex quinquefasciatus* for 4.6 hr at a concentration of 2mg/cm$^2$ and patchouli alcohol, its major constituent have shown repellent activity for a period of 280 min.[32] Khandagle *et al*., (2011) noted down that *Zingiber officinalis* rhizomes EO had shown repellent activity against *Aedes aegypti* and *Culex quinquefasciatus* with protection period of 5 hr each at a concentration of 0.5mg/cm$^2$.[33] Previously, Tawatsin *et al*., (2006) reported the repellent activity of EO of *Zingiber officinalis* rhizomes against *Aedes aegypti, Aedes albopictus, Anopheles dirus* and *Culex quinquefasciatus* with maximum protection periods of 3.4 hr, 7.2 hr, 8 hr and 7.7 hr in one minute exposure time when its 10% lotion in absolute alcohol plus excipients were used in experiment.[30] Kamaraj *et al*., (2011) reported that both methanolic and ethanolic extract of *Piper nigrum* seeds had mosquito repellent activity against *Anopheles stephensi* and *Culex quinquefasciatus* with maximum protection period of 150 min.[34] Tawatsin *et al*., (2006) illustrated the repellent activity of EO of *Piper nigrum* seeds against *Aedes aegypti, Aedes albopictus, Anopheles dirus* and *Culex quinquefasciatus* with maximum protection periods of 4.1 hr, 8 hr, 8 hr and 7.8 hr in one minute exposure time when its 10% lotion in absolute alcohol plus excipients were used in experiment.[30] Singh *et al*., (2009) reported that 10% hexane extract of *Cyperus rotundus* roots had shown repellency against *Anopheles culicifacies, Anopheles stephensi* and *Culex quinquefasciatus* with protection period of 4-6 hr, 6hr and 6 hr.[35] Tawatsin *et al*., (2006) reported the repellent activity of EO of *Curcuma longa* leaves against *Aedes aegypti, Aedes albopictus, Anopheles dirus* and *Culex quinquefasciatus* with protection periods of 3.6 hr, 8 hr, 8 hr and 8 hr in one minute exposure time.[30] Tawatsin *et al*., (2001) reported the mosquito repellent activity of 25% EO of *Curcuma longa* rhizomes with maximum protection periods of 4.5 hr, 8 hr, 8 hr ( with 5% vanillin) and 1 hr, 8 hr, 5 hr (without vanillin) against *Aedes aegypti, Anopheles dirus* and *Culex quinquefasciatus*.[25] Das *et al*., (2015) noted down that *Curcuma longa* rhizomes EO had maximum protection time of 96.2 min against *Aedes albopictus* at a concentration of 20%.[36] Tawatsin *et al*., (2006) reported the repellent activity of EO of *Alpinia galanga* rhizomes against *Aedes aegypti, Aedes albopictus, Anopheles dirus* and *Culex quinquefasciatus* with protection periods of 2.2 hr, 7.8 hr, 8 hr and 7.2 hr in one minute exposure time. Similarly, author also described the repellent activity of *Psidium guajava* leaves EO against *Aedes aegypti, Aedes albopictus, Anopheles dirus* and *Culex quinquefasciatus* with protection periods of 4.4 hr, 7.4 hr, 8 hr and 7.7 hr in one minute exposure time. In continuation of the above plants, repellent activity of *Piper betle* leaves EO against *Aedes aegypti, Aedes albopictus, Anopheles dirus* and *Culex quinquefasciatus* with protection periods of 2.3 hr, 7.6 hr, 8 hr and 7.8 hr in one minute exposure time was also noted down.[30] Yang and Ma, (2019) reported the repellency of *Citrus sinensis* leaves EO against *Aedes albopictus* with maximum protection period of 4-8 hr.[37]

Trongtokit *et al*., (2005) observed the repellent activity of 0.1 ml *Cymbopogon nardus* leaves EO against *Aedes aegypti, Anopheles dirus, Culex quinquefasciatus* and *Anopheles stephensi* with maximum protection periods of 2 hr, 1.16 hr, 1.6 hr and 8 hr.[38] Gillij *et al*., (2008) reported that 90% *Rosmarinus officinalis* EO have shown repellent activity for 90 min against *Aedes aegypti*.[13] Nasir *et al*., (2015) noted down the repellent activity of 10% *Ocimum basilicum* leaves EO against *Aedes aegypti* and *Aedes albopictus* with maximum protection periods of 64.34 min and 69.34 min.[21] Kamaraj *et al*., (2011) reported that methanolic extract of *Trachyspermum ammi* seeds had mosquito repellent activity against *Anopheles stephensi* and *Culex quinquefasciatus* with maximum protection period of 150 min.[34]

## Synergistic Combination of Essential Oils as a New Approach

As to prolong the protection time of mosquito repellents, combinations of essential oils are being built, tested and those showing synergistic effects may be further scaled up for commercial purposes also. For example, a 1:1:2 combination (20% concentration) of essential oils of *Curcuma longa* rhizomes, *Zanthoxylum limonella* and *Pogostemon heyneanus* leaves showed protection period of 329.4 min against *Aedes albopictus* mosquitoes, which is way more than their individual protection periods.[36] Combination of 50% clove: 50% thyme oil showed protection periods of 210 and 150 min against *Aedes aegypti* and *Anopheles albimanus* mosquito species.[60] Similarily, 0.075% concentration of combination of *Litsea cubeba* and *Litsea salicifolia* has proven to have significant synergistic effects against *Aedes aegypti*.[65] Combinations have been developed on the basis of the actual ratio of pure compounds present in the respective essential oils and tested for their repellent activity. Combination of perillaldehyde, perillyl alcohol, 1,8 cineole, limonene (29:4:10:7) of *Conyza newii* repelled 50% of mosquitoes at the lowest dose of 12 × 10−5 mg/cm$^2$. The blends of the main constituents of essential oil of *Suregada zanzibariensis* mixed in natural ratios showed higher repellency to *A. gambiae* s.s. than the parent oil.[66] Vanillin showed negligible repellency alone but enhances the protection period for about 2 hr when used in 5% concentration with most of the oils like cassia oil, rosemary oil, turmeric oil, and lemongrass oil etc.[67] Protection time of essential oil of *Zanthoxylum piperitum* and *Kaempferia galanga* increased from 60 to 190 min and 30 to 75 min against *Aedes aegypti* when mixed with vanillin, respectively.[40] Essential oil of *O. americanum* with vanillin provided 6.5-hr protection against *Aedes aegypti, C. quinquefasciatus* and *Anopheles dirus* in a caged experiment. Adding 5% vanillin with *C. winterinaius* oil provided 8-hr complete protection from *C. quinquefasciatus, Anopheles dirus,* and *Aedes aegypti* compared to 25% DEET.[25] A very few essential oil combinations have shown prominent synergistic effects so far. The high insect repellency and toxicity of the mixed oils might have resulted from the synergistic action of the main compounds in the oils. The mechanisms involved in how the interactions between the components of each essential oil result in the improvement of repellent activities, need further investigation.[9]

**Table 1:** **Biological Source, phytoconstituents and extraction methods with mosquito larvicidal and repellent activities of plant species.**

| S. No. | Biological Source | Common Name | Family | Parts Used | Major Constituents with % | Extraction Method | Analytical Technique | Activity Larvicidal Repellent | | Targeted mosquito | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | $LC_{50}$/ $LC_{90}$ | Max. Protection Period (min/hr) | | |
| 1. | *Coriandrum sativum* | Coriander | Apiaceae | Fruit | Linalool (83.6%) | Hydro-distillation | GC-EIMS | $LC_{50}$- 42.1 ppm | More than 1 hr | *Aedes albopictus* | [39] |
| 2. | *Zanthoxy lumpiperitum* | Japanese or Korean pepper | Rutaceae | Dried Fruit | Limonene (37.99%) | Steam distillation | GC/ MS | - | 1 hr (0.1 ml) 1-2.5 hr(+10% vanillin) | *Aedes aegypti* | [40] |
| 3. | *Hyptis suaveolens* | Bushmint | Lamiaceae/ Labiatae | Fresh Leaves | Sabinene (21.90%) | Hydro-distillation | GC-EIMS | $LC_{50}$- 240.3 ppm | 134.8 min (0.7496 µg/cm$^2$ of skin) | *Aedes albopictus* | [28] |
| 4. | *Salvia dorisiana* | Peach sage | Lamiaceae | Leaves | Aromadendrene (25.70%) | Hydro-distillation | GC–FID/ GC-MS | - | 92.4 min (0.4 µL/cm2 of skin) | *Aedes albopictus* | [41] |
| 5. | Wild *Ruta chalepensis* | Fringed rue | Rutaceae | Aerial parts | 2-Nonanone (37.4%) | Hydro-distillation | GC/ MS | $LC_{50}$- 35.66 ppm | 90 min (0.08 µL/cm2 of skin) | *Aedes albopictus* | [42] |
| 6. | *Curcuma longa* | Turmeric | Zingiberacee | Rhizomes | Tumerone (41.11%, artumerone(23.12%, curlone (19.14%),α-phellandrene(5.04%), eucalyptol (3.92%) | Steam distillation | GC/ MS | - $LC_{50}$-115.6 ppm | 8 hr (0.1 ml) 8 hr 8 hr 3.6 hr 5 hr, 8h (+ vanillin) (0.1ml) 8hr 1 hr, 4.5 hr (+ vanillin) 5% (22.4 min), 10% (43.8 min),20% (96.2 min),30%(104.8 min) (0.3 ml) | *Culex quinquefasciatus* *Anopheles dirus* *Aedes albopictus* *Aedes aegypti* *Culex quinquefasciatus* *Anopheles dirus* *Aedes aegypti* *Aedes albopictus* | [30] |
| 7. | *Zanthoxyl-um limonella* | Ma-khwaen | Rutaceae | Pericarp | - | Steam distillation | - | $LC_{50}$-11.0% v/v $LC_{50}$-15.5% v/v | 91.4 min(20%) - | *Aedes albopictus* *Culex quinquefasciatus* | [46, 44] |
| 8. | *Cupressus macrocarpa* | Monterey cypress | Lamiaceae | Aerial parts | Sabinene (21.8%) | Hydro-distillation | GC–FID | $LC_{50}$- 54.6 ppm | strong at low dose of 0.08 mg/cm$^2$ | *Aedes albopictus* | [45] |
| 9. | *Pogostemon cablin* | Patchouli | Lamiaceae | Leaves | Patchouli alcohol (22.62%)* | Hydro-distillation | GC-MS | - | 4.6 hr (2mg/cm$^2$) 280 min* | *Aedes aegypti* *Anopheles stephensi* *Culex quinquefasciatus* | [32] |

continued...

**Table 1: Con't**

| S. No. | Biological Source | Common Name | Family | Parts Used | Major Constituents with % | Extraction Method | Analytical Technique | Activity Larvicidal Repellent | | Targeted mosquito | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | $LC_{50}$/ $LC_{90}$ | Max. Protection Period (min/hr) | | |
| 11. | *Lavandula gibsoni* | Gibson`s Lavender, Nivli | Lamiaceae | Aerial parts | 1.α- terpinolene (22.22%) 2.Thymol (10.42%) | Hydro-distillation | GC–FID | $LC_{50}$- 62.79 ppm $LC_{50}$- 54.72 ppm $LC_{50}$- 48.3 ppm | - - 7 hr 25 min ($2mg/cm^2$) 1. 310 min ($0.4mg/cm^2$) 2. 250 min ($0.2mg/cm^2$) 1+2. 370 min ($0.6mg/cm^2$) | *Anopheles stephensi* *Culex quinquefasciatus* *Aedes aegypti* | [27] |
| 12. | *Mentha piperita* | Peppermint | Lamiaceae | Leaves | - | Hydro-distillation | - | $LC_{50}$-111.9ppm | 150 min 4 hr (7%) | *Aedes aegypti* *Aedes albopictus* | [37,47] |
| 13. | *Cymbopogon citratus* | Lemongrass | Poaceae | Aerial parts | - | Hydro-distillation | - | $LC_{50}$-33.7% v/v 69 ppm | 2-3 hr 3 hr | *Aedes aegypti* *Aedes albopictus* | [17,37,48] |
| | | | | Leaves | Geranial (41.30%) | Steam distillation | GC–FID | - | 1 hr ($1,2.5,5mg/cm^2$) | *Culextritaeniorhynchus* | |
| | | | | Stem | | Steam distillation | - | | | *Aedes aegypti* | |
| | | | | | - | | | - | 1.47 hr (0.1 ml of 10% soln.) 2.5 hr (3 ml of 25% soln.) | *Anopheles darlingi* | |
| 14. | *Amomum biflorum* | - | Zingiberacee | Leaves | - | Hydro-distillation | - | - | 16 min (10%) 80 min | *Aedes aegypti* *Culex quinquefasciatus* | [24] |
| 15. | *Boesenbergia rotunda* | Finger root | Zingiberacee | Roots, Rhizomes | - | Hydro-distillation | - | - | 30 min (10%) 260 min | *Aedes aegypti* *Culex quinquefasciatus* | [24] |
| 16. | *Curcuma zedoaria* | Zedoary, White Turmeric | Zingiberacee | Rhizomes | - | Hydro-distillation | - | - | 16 min (10%) 155 min | *Aedes aegypti* *Culex quinquefasciatus* | [24] |

continued...

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| S. No. | Biological Source | Common Name | Family | Parts Used | Major Constituents with % | Extraction Method | Analytical Technique | Activity Larvicidal Repellent | | Targeted mosquito | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | $LC_{50}$/ $LC_{90}$ | Max. Protection Period (min/hr) | | |
| 18. | *Zingiber officinalis* | Common ginger | Zingiberacee | Rhizomes | (E)-3,7-dimethyl-2,6-2,6-octadien al(24.72),eucalyptol(20.77), (Z)-3,7-dimethyl-2,6-oct-adienal(18.27), camphene (8.71) | Steam distillation | - | $LC_{50}$-154 ppm<br>$LC_{50}$-197 ppm | 5 hr (0.5mg/cm$^2$)<br>5 hr<br>3.4 hr (0.1 ml)<br>7.2 hr<br>8 h<br>7.7 hr | *Aedes aegypti*<br>*Culex quinquefasciatus*<br>*Aedes aegypti*<br>*Aedes albopictus*<br>*Anopheles dirus*<br>*Culex quinquefasciatus* | [33]<br>[30] |
| 19. | *Zingiber zerumbet* | Wild ginger | Zingiberacee | Rhizomes | - | Hydro-distillation | - | - | 17 min (10%)<br>185 min | *Aedes aegypti*<br>*Culex quinquefasciatus* | [24] |
| 20. | *Citrus aurantifolia* | Lime | Rutaceae | Peel<br>Leaves | - | Hydro-distillation | GC | - | 17 min (10%)<br>25 min<br>2 hr (15%) | *Aedes aegypti*<br>*Culex quinquefasciatus*<br>*Aedes aegypti* | [24]<br>[49] |
| 21. | *Citrus hystrix* | Kaffir lime | Rutaceae | Peel<br>Leaves | -<br>- | Hydro-distillation<br>Steam distillation | -<br>- | -<br>- | 11 min (10%)<br>75 min<br>1 hr<br>3 h (+ vanillin)<br>0.5 hr<br>1.5 hr (+ vanillin)<br>0.5 hr<br>2.5 hr (+ vanillin) | *Culex quinquefasciatus*<br>*Aedes aegypti*<br>*Aedes aegypti*<br>*Anopheles dirus*<br>*Culex quinquefasciatus* | [24]<br>[25] |
| 22. | *Citrus maxima* | Pomelo | Rutaceae | Peel | - | Hydro-distillation | GC | - | 11 min (10%)<br>25 min | *Aedes aegypti*<br>*Culex quinquefasciatus* | [24] |
| 23. | *Fortunella japonixa* | Kumquat | Rutaceae | Peel | - | Hydro-distillation | GC | - | 11 min (10%)<br>3 min | *Aedes aegypti*<br>*Culex quinquefasciatus* | [24] |
| 24. | *Litsea petiolata* | Litsea tree | Lauraceae | Leaves | - | Hydro-distillation | GC | - | 25 min (10%)<br>165 min | *Aedes aegypti*<br>*Culex quinquefasciatus* | [24] |

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**Table 1: Con't**

| S. No. | Biological Source | Common Name | Family | Parts Used | Major Constituents with % | Extraction Method | Analytical Technique | Activity Larvicidal Repellent | | Targeted mosquito | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | $LC_{50}$/ $LC_{90}$ | Max. Protection Period (min/hr) | | |
| 26. | *Cymbopog-on winterianus* | Citronella grass | Poaceae | Leaves | - | Steam distillation | - | - | 3 h<br>6.5 hr (+5% vanillin)<br>4 hr<br>8 hr (+5% vanillin)<br>8 hr | *Aedes aegypti*<br><br>*Anopheles dirus*<br><br>*Culex quinquefasciatus* | [25] |
| 27. | *Ocimum americanum* | Hairy basil | Lamiaceae | Leaves | E-Methyl Cinnamate (70.90%) | Steam distillation | - | - | 3 hr<br>6.5 hr (+5% vanillin)<br>4 hr<br>8 hr (+5% vanillin)<br>8 hr | *Aedes aegypti*<br><br>*Anopheles dirus*<br><br>*Culex quinquefasciatus* | [25] |
| 28. | *Cymbopogon nardus* | Citronella grass | Poaceae | Leaves | Citronellal, geraniol, citronellol, geranyl acetate | Steam distillation | - | - | 2 hr<br>1.16 hr<br><br>1.6 hr<br><br>8 hr | *Aedes aegypti*<br>*Anopheles dirus*<br>*Culex quinquefasciatus*<br>*Anopheles stephensi* | [38] |
| 29. | *Dianthus caryophyllum* | Clove pink | Caryophyllaeae | Flowers | A-Pinene, β-Pinene, α-Terpineol, β-Citro nellol, Geraniol | Steam distillation | GC/ MS | - | 4 hr | *Aedes aegypti* | [50] |
| 30. | *Citrus sinensis* | Orange | Rutaceae | Leaves | Limonene(71,3%), Myrcene (1,28%), (Z) Linalool (5,4%) | Microwave-assisted Hydro-distillation | GC | - | 4 – 8 hr | *Aedes albopictus* | [37] |
| 31. | *Mentha spicata* | Spearmint | Lamiaceae | Leaves | - | - | - | - | 7 hr | *Aedes albopictus* | [37] |
| 32. | *Eucalyptus globulus* | Eucalyptus | Myrtaceae | Leaves | - | - | - | - | 3 hr | *Aedes albopictus* | [37] |
| 33. | *Thymus vulgaris* | Thyme | Lamiaceae | - | Thymol (61%) | Hydro-distillation | GC-MS | - | 2 hr | *Aedes albopictus* | [51] |
| 34. | *Tribulus terrestres* | Burra gokharu | Zygophyllaceae | Leaves | - | - | - | $LC_{50}$- 64.6ppm | 4 hr ($1.5\ mg/cm^2$) | *Aedes aegypti* | [52] |
| 35. | *Kaempferia galanga* | Aromatic ginger | Zingiberaceae | Rhizomes | - | Steam distillation | GC/ MS | - | 0.25 hr<br>1.25 hr (+10% vanillin) | *Aedes aegypti* | [40] |

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**Table 1: Con't**

| S. No. | Biological Source | Common Name | Family | Parts Used | Major Constituents with % | Extraction Method | Analytical Technique | Activity Larvicidal Repellent | | Targeted mosquito | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | $LC_{50}$/ $LC_{90}$ | Max. Protection Period (min/hr) | | |
| 37. | *Curcuma aromatica* | Wild turmeric | Zingiberaceae | Rhizomes | Xanthorrizol(35,08),Curcumene(25,71%),7–meth-anoazulene(30,02%) | Steam distillation | GC/ MS | $LC_{50}$- 36.30 ppm (volatile oil)<br>$LC_{50}$- 57.15 ppm (hexane extract) | 0-0.5 hr (25%)<br>1-1.5 hr (25%) | *Aedes aegypti* | [53] |
| 38. | *Alpinia zerumbet* | Shell ginger | Zingiberaceae | Flowers | Eucalyptol(24,4%),Terpineno-4 - ol (26,0%),Sabinene(11,03%),Linalool(6,1%) | Hydro-distillation | GC–FID | - | Significant repellency (0.1%) | *Aedes aegypti* | [54] |
| 39. | *Alpinia galanga* | Galangal, Kulanjan | Zingiberaceae | Rhizomes | Eucalyptol(39,50%),1,3,3-trimethyl-2-oxabicyclo octan-6-ol acetate (28,61%), 4-allylphenyl acetate | Steam distillation | GC | - | 2.2 hr<br>7.8 hr<br>8 hr<br>7.2 hr | *Aedes aegypti*<br>*Aedes albopictus*<br>*Anopheles dirus*<br>*Culex quinquefasciatus* | [30] |
| 40. | *Lantana camara* | Red sage, Putus | Verbenaceae | Leaves | β-caryophyllene, (32%), α-humulene (12%) | Hydro-distillation | - | $LC_{50}$-42 ppm<br>$LC_{50}$-31 ppm | 30 min<br>30 min (ethyl acetate extract) | *Anopheles stephensi*<br>*Culex quinquefasciatus* | [34] |
| 41. | *Nelumbo nucifera* | Lotus | Nelumbonaceae | Leaves | - | Hydro-distillation | GC-MS | $LC_{50}$-34.76 Ppm<br>$LC_{50}$-37.49 ppm (methanol extract) | 150 min (500ppm)<br>150 min | *Anopheles stephensi*<br>*Culex quinquefasciatus* | [34] |
| 42. | *Phyllanthus amarus* | Indian gooseberry | Phyllanthaceae | Leaves | - | Hydro-distillation | GC-MS | $LC_{50}$-37 ppm<br>$LC_{50}$-48 ppm (methanol extract) | 150 min (500ppm)<br>150 min | *Anopheles stephensi*<br>*Culex quinquefasciatus* | [34] |

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**Table 1: Con't**

| S. No. | Biological Source | Common Name | Family | Parts Used | Major Constituents with % | Extraction Method | Analytical Technique | Activity Larvicidal Repellent | | Targeted mosquito | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | $LC_{50}$/ $LC_{90}$ | Max. Protection Period (min/hr) | | |
| 44. | *Piper betle* | Betel nut | Piperaceae | Leaves | 4-allyl-2-methoxy-phenol acetate (31.47), 3-allyl-6-methoxyphenol (25.96), 4-allyl-phenylacetate (5.21) | Steam distillation | GC | - | 2.3 hr<br>7.6 hr<br>8 hr<br>7.8 hr | *Aedes aegypti*<br>*Aedes albopictus*<br>*Anopheles dirus*<br>*Culex quinquefasciatus* | [30] |
| 45. | *Datura stramonium* | Thorn apple, Angel's trump-et | Solanaceae | Leaves | - | Hydro-distillation | - | - | 120 min (3mg/ml of extract) | *Anopheles gambiae* | [55] |
| 46. | *Citrus grandis* | Pomelo | Rutaceae | Fruit peel | - | Hydro-distillation | GC | | 2 hr (15% conc.) | *Aedes aegypti* | [49] |
| 47. | *Psidium guajava* | Guava | Myrtaceae | Leaves | Caryophyllene oxide (21,97%), 4,4-di-methyltetracyclo(2,5%) tridecan-9-ol (14,49%),caryophyllene (11,76%), ±-(E)-nerolidol (9,39) | Steam distillation | GC | - | 4.4 hr<br>7.4 hr<br>8 hr<br>7.7 hr | *Aedes aegypti*<br>*Aedes albopictus*<br>*Anopheles dirus*<br>*Culex quinquefasciatus* | [30] |
| 48. | *Syzygium aromaticum* | Clove | Myrtaceae | Flowers | Eugenol (80,08%) | Steam distillation | - | - | 80.33 min (10%)<br>60 min | *Aedes aegypti*<br>*Anopheles dirus* | [56] |
| 49. | *Eucalyptus globulus* | Nilgiri | Myrtaceae | Leaves | - | Steam distillation | - | - | 81.67 min (10%)<br>95 min | *Aedes aegypti*<br>*Anopheles dirus* | [56] |
| 50. | *Azadirachta indica* | Neem | Meliaceae | Leaves | - | Steam distillation | - | - | 246 min( 0.1 mL of the 10 % oil)<br>256 min | *Aedes aegypti*<br>*Aedes albopictus* | [21] |
| 51. | *Sida acuta* | Bala | Malvaceae | Leaves | - | Steam distillation | - | $LC_{50}$-47.91 ppm<br>$LC_{50}$-42.08 ppm<br>$LC_{50}$-38.64 ppm | 120 min(5 mg/cm$^2$)<br>150 min<br>180 min | *Culex quinquefasciatus*<br>*Aedes aegypti*<br>*Anopheles dirus* | [57] |
| 52. | *Erythrina indica* | Indian Coral Tres | Leguminosae | Leaves | - | Hydro-distillation | - | - | 210 min<br>(5 mg/cm$^2$)<br>210 min<br>180 min<br>(methanol extract) | *Anopheles stephensi*<br>*Aedes aegypti*<br>*Culex quinquefasciatus* | [23] |

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**Table 1: Con't**

| S. No. | Biological Source | Common Name | Family | Parts Used | Major Constituents with % | Extraction Method | Analytical Technique | Activity Larvicidal Repellent | | Targeted mosquito | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | $LC_{50}$/ $LC_{90}$ | Max. Protection Period (min/hr) | | |
| 54. | *Ervatamia coronaria* | Nanthiyavattai | Apocynaceae | Leaves | - | Steam distillation | - | $LC_{50}$-96.15 ppm<br>$LC_{50}$-89.59 ppm<br>$LC_{50}$- 79.08 ppm<br>(Benzene extract) | 120 min<br>(5 mg/cm$^2$)<br>150 min<br>180 min | *Culex quinquefasciatus*<br>*Aedes aegypti*<br>*Anopheles stephensi* | [58] |
| 55. | *Cassia siamea* | Senna siamea | Leguminosae | Leaves | - | Hydro-distillation | GC-MS | $LC_{50}$-53.94 ppm<br>$LC_{50}$-46.61 ppm<br>(methanol extract) | 150 min (500ppm)<br>150 min | *Anopheles stephensi*<br>*Culex quinquefasciatus* | [34] |
| 56. | *Litsea cubeba* | Mountain Pepper | Lauraceae | Leaves | (E)-3,7-dimethyl, 2,6-octadienal (75,56%), 6-methyl-5-hepten-2- one (7,92%) | Steam distillation | GC | - | 2.5 hr<br>7.7 hr<br>8 hr<br>7.5 hr | *Aedes aegypti*<br>*Aedes albopictus*<br>*Anopheles dirus*<br>*Culex quinquefasciatus* | [30] |
| 57. | *Ocimum sanctum* | Tulsi | Lamiaceae | Leaves | - | Hydro-distillation | GC-MS | - | 6 hr (20%) | *Aedes aegypti* | [19] |
| 58. | *Plectranthus amboinicus* | Indian borage | Lamiaceae | Leaves | - | Hydro-distillation | GC-MS | - | 6 hr (20%) | *Aedes aegypti* | [19] |
| 59. | *Origanum scabrum* | Ornamental plant | Lamiaceae | Leaves | Carvacrol (48,2%) etimol (16,6%), p –Cymene(3,9%),γ-Terpinene (3,6%) | Hydro-distillation | GC-MS | $LC_{50}$-61.65 ppm<br>$LC_{50}$-67.13 ppm<br>$LC_{50}$-72.45 Ppm<br>$LC_{50}$-78.87 Ppm | 210 min<br>180 min<br>150 min<br>120 min | *Anopheles stephensi*<br>*Aedes aegypti*<br>*Culex quinquefasciatus*<br>*C. Tritaeniorhynchus* | [59] |
| 60. | *Ocimum basilicum* | Niazbow | Lamiaceae | Leaves | Estragol (58,26%), limonene + β-fellandrene(19,41%),fenchone(10.1%),α-Phellendrene (4, 37%) | Hydro-distillation | - | - | 64.34 min (10%)<br>69.34 min | *Aedes aegypti*<br>*Aedes albopictus* | [21] |

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**Table 1: Con't**

| S. No. | Biological Source | Common Name | Family | Parts Used | Major Constituents with % | Extraction Method | Analytical Technique | Activity Larvicidal Repellent | | Targeted mosquito | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | $LC_{50}$/ $LC_{90}$ | Max. Protection Period (min/hr) | | |
| 62. | *Juniperus communis* | Aaraar, Haubera | Cupressaceae | Berry | Sabinene (50,8%) β-myrcene(13,2%), limonene (12,2%), cyclohexanol(6,9%) | - | GC/ MS | - | significant repellency at 0.005mg/cm$^2$ conc. | *Culex pipens* | [60] |
| 63. | *Cryptomeria japonica* | Japanese Cedar, ,Dhupi Sallaa | Cupressaceae | Leaf | Ent-kaur-16-ene 3- carene | Hydro-distillation | GC-FID GC/ MS | - | 20 min 20 min | *Aedes aegypti* *Aedes albopictus* | [61] |
| 64. | *Eclipta alba* | Bhringraj | Compositse | Leaves | - | Hydro-distillation | GC | - | 150 min (2.5 mg/cm$^2$) 150 min (ethyl acetate extract) | *Culex quinquefasciatus* *Aedes aegypti* | [29] |
| 65. | *Tagetes minuta* | Wild Marigold | Compositse | - | Limonene(66,3%), α- Pinene(11, 8%) (E)-Ocimenone (19,1%) | Hydro-distillation | GC/ MS | - | 90 min (90%) | *Aedes aegypti* | [13] |
| 66. | *Sphaeranthus indicus* | East Indian globe thistle | Compositse | Flowers | 3,5-di-te-rcbutil-4-hidroxi benzaldeído(24,9%),benzeno, 2-(1,1-dimetiletil)–1,4-dimetox i(22,54%). | Steam distillation | GC | $LC_{50}$- 130ppm $LC_{50}$- 140ppm | 120 min 120 min | *Culex quinquefasciatus* *Aedes aegypti* | [62] |
| 67. | *Asparagus racemosus* | Shatavari | Asparagaceae | Root | - | Hydro-distillation | - | - | 180 min (5 mg/cm$^2$) 180 min 150 min | *Anopheles stephensi* *Aedes aegypti* *Culex quinquefasciatus* | [23] |
| 68. | *Angelica sinensis* | Ginseng | Apiaceae | Rhizome and root | 3-N-Butylphthalide (25.81%), Butylidenephthalide (50.71%),β-espatulenol(2.52%), Ligustilide (1.92%) | Steam distillation | GC/ MS | - | 7.5 hr (hexane extract) | *Aedes aegypti* | [20] |

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**Table 1: Con't**

| S. No. | Biological Source | Common Name | Family | Parts Used | Major Constituents with % | Extraction Method | Analytical Technique | Activity Larvicidal Repellent | | Targeted mosquito | References |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | $LC_{50}$/ $LC_{90}$ | Max. Protection Period (min/hr) | | |
| 70. | *Apium graveolens* | Root celery | Apiaceae | Seed | D -limoneno (80%) | Hydro-distillation | - | $LC_{50}$- 13.22 Ppm | 150 min | *Aedes aegypti* | [26] |
| 71. | *Cananga odorata* | Ylang-Ylang tree | Annonaceae | - | Linalool (21,08%), Linalool acetate (16,14%), α-pinene(12,73%), Eugenol(8,86%) | Hydro-distillation | GC | - | 88.7 min<br>126.7 min | *Aedes aegypti*<br>*Culex quinquefasciatus* | [64] |
| 72. | *Andrographis paniculata* | Creat or green chiretta | Acanthaceae | - | - | Hydro-distillation | GC | - | 210 min (5 mg/cm$^2$)<br>180 min (methanol extract) | *Culex quinquefasciatus*<br>*Aedes aegypti* | [29] |
| 73. | *Dysphania ambrosioid-es* | Sugandha vastuka | Amaranthaceae | - | α-ascaridol (99,4%) b-Curcumene (0,1%) | Hydro-distillation | GC-MS | | 60 min (90%) | *Aedes aegypti* | [13] |
| 74. | *Rosmarinus officinalis* | Gulmehendi | Lamiaceae | Flowers | Camphor (33.6%), verbenone (24.9%), (E)-Caryophyllene (14.8%), borneol, bornyl acetate, α-terpineol, terpinen-4-ol | Hydro-distillation | GC-MS | | 90 min (90%) | *Aedes aegypti* | [13] |
| 75. | *Achyranthes aspera* | Aghara | Amaranthaceae | Leaf[1]<br>Stem[2] | - | Steam distillation | - | $LC_{50}$- 668ppm<br>$LC_{50}$- 761ppm<br>$LC_{50}$- 355ppm<br>$LC_{50}$- 437ppm | 1 h[1]<br>2 h[2]<br>1 h[1]<br>2 h[2] (0.5 mg/cm$^2$) | *Aedes aegypti*<br>*Culex quinquefasciatus* | [33] |

## CONCLUSION

Mosquitoes are majorly responsible for transmitting mosquito-borne diseases like malaria, dengue, chikungunya, zika, yellow fever and others. Prolong use of harmful chemical insecticide not only cause development of resistance in mosquitoes but also have shown adverse effects on humans as well as on environment. Plant extracts, essential oils and their chemical constituents also shown optimal repellent potential against various mosquito species. In addition, the synergistic combinations of EOs have also found to be effective against broad range of mosquitoes with least side-effects as well as combining these individual EOs with vanillin increases the total protection period against mosquitoes. Further research is required in the arena of EOs combination, to find most effective mosquito repellent combination against dengue and malaria causing mosquitoes and that can also have capability to be formulated as mosquito repellent preparations in future too.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## ABBREVIATIONS

**ITNs:** insecticide-treated nets; **LLINs:** Long-Lasting Insecticide-Treated Nets; **DDT:** Dichlorodiphenyltrichloroethane; **DEET:** N,N-diethyl-m-toluamide, IR3535: 3-(N-Butyl-N-acetyl)-amino propionic acid); **EO:** Essential oils; **GC:** Gas Chromatography; **GC-MS:** Gas Chromatography-Mass Spectroscopy; **NH3:** Ammonia; **IRS:** Indoor residual spraying; **DEPA:** Diethyl Phenyl Acetamide; **$LC_{50}$:** Lethal Concentration; **RD50, 95:** Repellent doses; **WHO:** World Health Organization; **PT:** Percentage of Repellency; **µL/cm2:** Microlitre per centimeter square; **µL/mm2:** Microlitre per millimeter square; **mm:** Millimeter; **PR:** Percentage repellency; **min:** Minutes; %: Percentage; **Hr:** Hours; **α:** Alpha; **Mg:** Microgram; **cm2:** Centimeter square; **mL:** Millilitre; **µL:** Microliter; **CSIR:** Council of Scientific and Industrial Research; **GC-EIMS:** Gas Chromatography with Electron Impact Mass Spectrometry; **FID:** Flame Ionization Detector: **Conc.:** Concentration; **%w/v:** per cent weight by volume; **Fig.:** Figure; **Gm:** Gram; **Mg:** Milligram; **PPM:** Parts Per Millions; **Sec:** Seconds; **%w/w:** per cent weight by weight; **mm:** millimetre; **v/v:** volume by volume; **DBT:** Department of Biotechnology; **JRF:** Junior Research Fellow.

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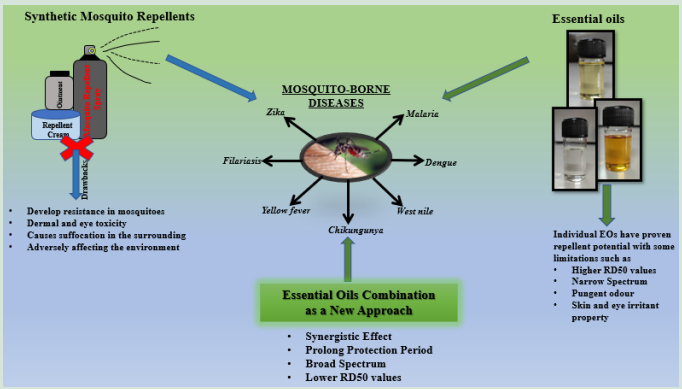
## GRAPHICAL ABSTRACT




## SUMMARY


- Mosquitoes are responsible for spreading of vector-borne diseases.
- EO of particular plant is mostly extracted by hydro-distillation and steam distillation.
- GC/MS, GC-EIMS, GC-FID are the techniques used for identification of EO components.
- The EO combinations are also used as effective mosquito repellent.
- Due to provided synergism as well as negation of harmful effects associated with individual oils.
- Incorporation of vanillin also enhances the efficacy and maximize the protection period provided by EOs.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