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# Review Study on Larvicidal and Mosquito Repellent Activity of Volatile Oils Isolated from Medicinal Plants

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***Abstract –*** *Mosquito is a vector for serious human diseases like dengue fever, hemaorrhagic dengue fever and chikungunya, .yellow fever, malaria, filaria and encephalitis among these dengue, hemaorrhagic dengue and chikungunya are highly endemic diseases in Southeast Asian and African countries, causing millions of deaths each and every year. Mosquito repellents thus play a major role in preventing man-mosquito contact and there by minimize the chance of infections and its adverse effects. The development of resistance to chemical insecticides, results rebounding vectorial capacity. Synthetic repellents are chemicals which used worldwide for protection against mosquito-borne diseases and it adversely affects the environment by contaminating water, soil and air. There is an urgent need to find alternatives to the synthetic insecticides. Plants are rich source of alternative agents for control of mosquitoes and its vectors. Extracts and isolated compounds from different plant families have been evaluated for their promising larvicidal and mosquito repellent activities. Literature has documented that essential oils and extracts have been traditionally used as effective repellents. The essential oils whose repellent activities have been demonstrated, as well as the importance of the synergistic effects among their components are the main focus of this review study. Essential oils are volatile mixtures of hydrocarbons with a diversity of functional groups, and their repellent activity has been linked to the presence of monoterpenes and sesquiterpenes. The present review study focused the larvicidal potential and mosquito repellent activity of different volatile oils of medicinal plants. From an economical point of view synthetic chemical is still more frequently used as repellents than essential oils; these essential oils have the potential to provide efficient and can be used as a cheap, eco-friendly, safer for humans and the environment and also efficient alternative to the chemical larvicides.*

***Keywords— Essential oils, Larvicidal activity, Medicinal Plants, Mosquito repellents, Volatile oils.***

## I. INTRODUCTION

Mosquitoes transmit serious human diseases, causing millions of deaths every year and the development of resistance to chemical insecticides, resulting in rebounding vectorial capacity. Mosquito has approximately 3500 species and present in tropical and subtropical regions of the world [1].Major genera of mosquitoes that act as vector for various disease including dengue, chikungunya, malaria, yellow fever, filariasis, Japanese encephalitis, Lyme disease, andepidemic polyarthritis [2, 3]. Among these mosquito borne diseases dengue, fever dengue hemaorrhagic fever, yellow fever and chikungunya are endemic in Southeast Asian countries [4]. These are transmitted by *Aedes aegypti* (Linn.) [5] *Anopheles stephensi* and *Culex quinquefasciatus.* Mosquito repellents thus play a major role in preventing man-mosquito contact and there by minimize the chance of infectious diseases. Synthetic repellents, such as DEET (Diethyl-meta-toluamide or N, N- diethyl-3-methyl benzamide (IUPAC Name)), are used worldwide for protection against mosquito-borne diseases. However, DEET has an unpleasant odor, can damage plastics and synthetic rubber and exhibits a high level of skin penetration [6]. Moreover, concerns have been raised over the safety of DEET and other synthetic compounds [7]; one of the methods available for controlling the mosquitoes is use of synthetic insecticides. Synthetic insecticides adversely affect the environment by contaminating water, soil and air. There is an urgent need to find alternatives to the synthetic insecticides.

Plants and its isolated compounds are alternative agents for control of mosquitoes, because they possess bioactive chemicals, which act against limited number of species including specific target-insects and are eco-friendly [8].Traditionally plant based products have been used in human communities for many centuries for managing insects. Several secondary metabolites present in plants serve as a defense mechanism against insect attacks. These bioactive chemical may act as insecticides, repellents, anti-feedants, moulting hormones, juvenile hormone mimics, growth inhibitors, anti-moulting hormones as well as

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attractants. Plant based pesticides are less toxic, delay the development of resistance because of its new structure and easily biodegradable [9].

Several plant extracts and isolated compounds from different plant families have been evaluated for their promising larvicidal activities [10]. About 2000 species of terrestrial plants have been reported for their insecticidal properties [11]. Medicinal plants are more potent, eco-safe and low-cost which is easily available and have become increasingly popular as safe and biodegradable mosquito repellents [12], it is less or no adverse effect to the environment.

Plant based products does not have any hazardous effect on ecosystem. Recent research has proved that effectiveness of plant derived compounds, such as saponine [13], steroids [14, 15], isoflavonoids [16], essential oils [17], alkaloids and tannins [18] has potential mosquito larvicides. Plant secondary metabolites and their synthetic derivatives provide alternative source in the control of mosquito [19, 20].

### 1.1. Mode of action of essential oils

Essential oils being complex mixtures of volatile organic compounds are generally produced as secondary metabolites in plants. They are constituted by hydrocarbons (terpenes and sesquiterpenes) and oxygenated compounds (alcohols, esters, ethers, aldehydes, ketones, lactones and phenols). Essential oils have high repellency against arthropod species [21]. Literature has documented that essential oils and extracts have been traditionally used as effective repellents. The metabolites like the monoterpenes such as α-pinene, cineole, eugenol, limonene, terpinolene, citronellol, citronellal, camphor and thymol are the common constituents in a number of essential oils presenting mosquito repellent activity [22]. Literature cites that hairs on the mosquito antennae are temperature and moisture sensitive. The repellent molecules thus interacts with the female mosquito olfactory receptors thereby blocking the sense of smell which therefore comes as an hurdle in the recognition of host by the mosquitoes [23].

Elucidation of the mode of action of essential oils and their constituents is of practical importance for insect control because it may give useful information on the most appropriate formulation and delivery means. Volatile oil can disrupt communication in mating behavior of insect by blocking the function of antennal sensilla and unsuccessful mating could lead to a lower fecundity and ultimately lower the population of insect pest [24]. Rapid action of essential oils or its constituents against insect pests is an indicative of neurotoxic actions. The present review study carried out to validate the larvicidal potential and mosquito repellent activity of different volatile oils of medicinal plants.

## II. LITERATURE SURVEY

Manimaran et al., evaluated larvicidal efficacy of the most promising oils such as mentha (*Mentha piperita*), clove (*Myrtus caryophyllus*) and calamus oils (*Acorus calamus*) which recorded low $LC_{50}$ and $LC_{90}$ values with 95% confidence lower and upper limits. Eucalyptus oil showed the least larvicidal activity with $LC_{50}$and $LC_{90}$ values for larvicidal activity against *Anopheles stephensi*. Some plant oils also tested against *Culex quinquefasciatus*, the most promising oils were calamus, mentha and lemon oils which recorded $LC_{50}$and$LC_{90}$values with 95% confidence lower limits and upper limits for larvidial activity. Citronella oil showed least larvicidal activity with $LC_{50}$and $LC_{90}$ values. Among the oils against *Aedes aegypti*, Mentha, citronella and clove oils showed the most potent larvicidal activity and recorded $LC_{50}$and $LC_{90}$values with 95% confidence lower and upper limits. Eucalyptus oil showed the least effective larvicidal activity with $LC_{50}$and $LC_{90}$values [25].

Cavalcanti et al., reported the most active essential oils against third instar larvae of *A. aegypti* were those of *O. gratissimun* ($LC_{50}$ 60 ppm), *O. americanum* ($LC_{50}$ 67 ppm), *L. sidoides* ($LC_{50}$ 63 ppm), and *C. citrates* ($LC_{50}$ 69 ppm). They finally concluded the essential oils of *O. americanum* and *O. gratissimun* showed as potent as *L. sidoides* and *C. citrates* in the larvicidal activity against *A. aegypti* and caused 100% mortality at a concentration of 100 ppm [17]. Sukumar et al., reported that *C. citrates* causes significant growth inhibition and mortality in later developmental stages of *A. aegypti* [26].

One research study revealed that the essential oils from *Mentha longifolia* L., and *Lavandula dentata* L. were evaluated for their insecticidal and repellent activity against adult females of *Culex pipiens* L. This study concludes *Lavandula dentata* oil showed higher repellent activity than *Mentha longifolia* oil against adults of *Culex pipiens*; paraffin oil significantly prolonged the time of protection for the two oils. The longest time of protection was recorded 165 min for *L dentata* oil, at 1 μl/$cm^2$, when the tested oils were applied in paraffin oil. The researcher suggested the two oils were effective as repellent substances when compared with commercial materials and also recommended further studies to isolate the most effective mosquito control agents from these oils [27].

Using a GC/MS, 24, 17, 20, 21, and 12 compounds were determined by Nataya Sutthanont et al., from essential oils of *Citrus hystrix*, *Citrus reticulata*, *Zingiber zerumbet*, *Kaempferia galanga*, and *Syzygium aromaticum*, respectively. The author analysed the principal constituents found in peel oil of *C. hystrix* were *β*-pinene and *d*-limonene, followed by terpinene-4-ol. Compounds in *C. reticulata* peel oil consisted mostly of *d*-limonene and *γ*-terpinene. The oils obtained from *Z. zerumbet* rhizome had *α*-humulene and zerumbone as major components. The most abundant compounds in *K. galanga* rhizome oil were 2-propeonic acid, pentadecane, and ethyl-*p*-ethoxycinnamate. The main component of *S. aromaticum* bud oil was eugenol, with minor amounts of *trans*-caryophyllene. The researcher

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assessed larvicidal efficacy and demonstrated that all essential oils were toxic against both pyrethroid-susceptible and resistant *Ae. aegypti* laboratory strains at $LC_{50}$, $LC_{95}$, and $LC_{99}$ levels. They conclude and documented the promising larvicidal potential of essential oils from edible herbs, which used in controlling vectors of mosquito borne disease [28].

Pavela et al., documented twenty samples of essential oils obtained from *Mentha aquatica*, *M. longifolia*, *M. spicata*, *M. suaveolens*, *M. piperita*, *M. piperita* var. *crispa*, *M. villosa*, and *Pulegium vulgare* were tested for larvicidal activity against *Culex quinquefasciatus*. Essential oils obtained via hydro-distillation and subsequently analysed by gas chromatography-mass spectrometry (GC-MS). The researcher analysed the concentrations causing 50% or 90% larval mortality. Finally they conclude essential oils of *M. longifolia* and *M. suaveolens*, which were containing a majority of piperitenone oxide, and also had the highest larvicidal effects [29].

*Table.1: Essential Oils that have shown Larvicidal and Mosquito Repellent Activity.*

| Vector's Scientific name | Plant Species | Family Name | Plant Parts Used | Reference |
|---|---|---|---|---|
| *Aedes aegypti* | *Mentha piperita* | Lamiaceae | Commercial | Manimaran et al., (2012) |
| *Aedes aegypti* | *Myrtus caryophyllus* | Myrtaceae | Commercial | Manimaran et al., (2012) |
| *Aedes aegypti* | *Acorus calamus* | Acoraceae | Commercial | Manimaran et al., (2012) |
| *Aedes aegypti* | *Cinnamomum* | Lauraceae | Commercial | Manimaran et al., (2012) |
| *Aedes aegypti* | *zeylanicum* | Cardiopteridaceae | Commercial | Manimaran et al., (2012) |
| *Aedes aegypti* | *Citronella mucronata* | Myrtaceae | Commercial | Manimaran et al., (2012) |
| *Aedes aegypti* | *Eucalyptus tereticornis* | Rutaceae | Commercial | Manimaran et al., (2012) |
| *Aedes aegypti* | *Citrus limon (L.)* | Rutaceae | Commercial | Manimaran et al., (2012) |
| *Aedes aegypti* | *Citrus sinensis* | Rutaceae | Dried Fruits | Choochote et al., (2007) |
| *Aedes aegypti* | *Zingiber piperitum* | Compositae | N.A | Gillij et al., (2008) |
| *Aedes aegypti* | *Baccharis spartioides* | Verbenaceae | N.A | Gillij et al., (2008) |
| *Aedes aegypti* | *Aloysia citriodora* | Poaceae | Fresh aerial parts | Oyedele et al., (2002) |
| *Aedes aegypti* | *C. citratus* | Lamiaceae | Leaves | Prajapati et al., (2005) |
| *Aedes aegypti* | *O. basilicum* | Lamiaceae | Shoot | Prajapati et al., (2005) |
| *Aedes aegypti* | *Rosmarinus offinalis* | Lauraceae | Bark | Prajapati et al., (2005) |
| *Aedes aegypti* | *Cinnamomum* | Lamiaceae | Commercial | Trongtokit et al., (2005) |
| *Aedes aegypti* | *zeylanicum* | Myrtaceae | Commercial | Trongtokit et al., (2005) |
| *Aedes aegypti* | *Pogostemon cablin* | Rutaceae | Leaves | Trongtokit et al., (2005) |
| *Aedes aegypti* | *Syzygium aromaticum* | Poaceae | Leaves | Trongtokit et al., (2005) |
| *Aedes aegypti* | *Z. limonella* | Caryophyllaceae | Flowers | Tunon et al., (2006) |
| *Aedes aegypti* | *C. nardus* | Caryophyllaceae | Flowers | Tunon et al., (2006) |
| *Aedes aegypti* | *D. caryophyllum* | Lamiaceae | Leaves with | Cavalcanti et al., (2004) |
| *Aedes aegypti* | *D. caryophyllum* | Lamiaceae | Bloom | Cavalcanti et al., (2004) |
| *Aedes aegypti* | *Ocimum gratissimum* | Geraniaceae | Leaves with | Cavalcanti et al., (2004) |
| *Aedes aegypti* | *O. americanum* | Poaceae | Bloom | Cavalcanti et al., (2004) |
| *Aedes aegypti* | *Pelargonium sidoides* | Poaceae | Leaves | Sukumar et al., (1991) |
| *Aedes aegypti* | *C. citratus* | Rutaceae | Leaves | Nataya et al., (2010) |
| *Aedes aegypti* | *C. citratus* | Rutaceae | Leaves | Nataya et al., (2010) |
| *Aedes aegypti* | *Citrus histrix* | Zingiberaceae | Fruits | Nataya et al., (2010) |
| *Aedes aegypti* | *Citrus reticulata* | Zingiberaceae | Fruits | Nataya et al., (2010) |
| *Aedes aegypti* | *Zingiber zerumpet* | Myrtaceae | Rhizome | Nataya et al., (2010) |
| *Anapheles stephensi* | *Kaemferia galanga* | Lamiaceae | Rhizome | Manimaran et al., (2012) |
| *Anapheles stephensi* | *Syzygium aromaticum* | Myrtaceae | Flower | Manimaran et al., (2012) |
| *Anapheles stephensi* | *Mentha piperita* | Acoraceae | Commercial | Manimaran et al., (2012) |
| *Anapheles stephensi* | *Myrtus caryophyllus* | Lauraceae | Commercial | Manimaran et al., (2012) |
| *Anapheles stephensi* | *Acorus calamus* | Cardiopteridaceae | Commercial | Manimaran et al., (2012) |
| *Anapheles stephensi* | *Cinnamomum* | Myrtaceae | Commercial | Manimaran et al., (2012) |
| *Anapheles stephensi* | *zeylanicum* | Rutaceae | Commercial | Manimaran et al., (2012) |
| *Anapheles stephensi* | *Citronella mucronata* | Rutaceae | Commercial | Manimaran et al., (2012) |
| *Anapheles stephensi* | *Eucalyptus tereticornis* | Lamiaceae | Commercial | Prajapati et al., (2005) |
| *Anapheles stephensi* | *Citrus limon (L.)* | Lamiaceae | Commercial | Prajapati et al., (2005) |
| *Anapheles stephensi* | *Citrus sinensis* | Lauraceae | Leaves | Prajapati et al., (2005) |

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|---|---|---|---|---|
| Culex. quinquefasciatus | *O. basilicum* | Lamiaceae | Shoot | Pavela et al., (2014) |
| Culex. quinquefasciatus | *Rosmarinus offinalis* | Lamiaceae | Bark | Pavela et al., (2014) |
| Culex. quinquefasciatus | *Cinnamomum* | Lamiaceae | Stage of full | Pavela et al., (2014) |
| Culex. quinquefasciatus | *zeylanicum* | Lamiaceae | Bloom | Pavela et al., (2014) |
| Culex. quinquefasciatus | *Mentha aquatica* | Lamiaceae | Stage of full | Pavela et al., (2014) |
| Culex. quinquefasciatus | *Mentha longifolia* | Learuophullaceae | Bloom | Pavela et al., (2014) |
| Culex. quinquefasciatus | *Mentha spicata* | Lamiaceae | Stage of full | Pavela et al., (2014) |
| Culex. quinquefasciatus | *Mentha suaveolence* | Lamiaceae | Bloom | Manimaran et al., (2012) |
| Culex. quinquefasciatus | *Mentha piperita* | Myrtaceae | Stage of full | Manimaran et al., (2012) |
| Culex. quinquefasciatus | *Mentha villosa* | Acoraceae | Bloom | Manimaran et al., (2012) |
| Culex. quinquefasciatus | *Mentha pulegium* | Lauraceae | Stage of full | Manimaran et al., (2012) |
| Culex. quinquefasciatus | *Mentha piperita* | Cardiopteridaceae | Bloom | Manimaran et al., (2012) |
| Culex. quinquefasciatus | *Myrtus caryophyllus* | Myrtaceae | Stage of full | Manimaran et al., (2012) |
| Culex. quinquefasciatus | *Acorus calamus* | Rutaceae | Bloom | Manimaran et al., (2012) |
| Culex. quinquefasciatus | *Cinnamomum* | Rutaceae | Stage of full | Manimaran et al., (2012) |
| Culex. quinquefasciatus | *zeylanicum* | Lamiaceae | Bloom | Ansari et al., (2000) |
| Culex. quinquefasciatus | *Citronella mucronata* | Lamiaceae | Commercial | Prajapati et al., (2005) |
| Culex. quinquefasciatus | *Eucalyptus tereticornis* | Lauraceae | Commercial | Prajapati et al., (2005) |
| Culex. quinquefasciatus | *Citrus limon (L.)* | Graminae | Commercial | Pushpanathan et al., (2006) |
| Culex. quinquefasciatus | *Citrus sinensis* | Zingiberaceae | Commercial | Pushpanathan et al., (2008) |
| Culex. quinquefasciatus | *Mentha piperita* | Lamiaceae | Commercial | Rajkumar and Jebanesan |
| Culex. quinquefasciatus | *O. basilicum* | Solanaceae | Commercial | (2005) |
| Culex. quinquefasciatus | *Cinnamomum* | Poaceae | Commercial | Rajkumar and Jebanesan |
| Culex. quinquefasciatus | *zeylanicum* | Lamiaceae | Commercial | (2005) |
| Culex. quinquefasciatus | *C. citratus* | Rutaceae | Fresh leaves | Tawatsin et al., (2001) |
| Culex. quinquefasciatus | *Zingiber officinalis* | Lamiaceae | Leaves | Tawatsin et al., (2001) |
| Culex. quinquefasciatus | *Moschosma* | Myrtaceae | Bark | Trongtokit et al., (2005) |
| | *polystachyum* | | N.A | Trongtokit et al., (2005) |
| | *Solanum* | | Rhizomes | Trongtokit et al., (2005) |
| | *xanthocarpum* | | Fresh Leaves | |
| | *C. winterianus* | | Fresh Leaves | |
| | *O. americanum* | | Leaves | |
| | *Z. limonella* | | Leaves | |
| | *Pogostemon cablin* | | Leaves | |
| | *Syzygium aromaticum* | | Commercial | |
| | | | Commercial | |

N.A – Not Available, Commercial – Essential oil purchased commercially.

One study revealed that the essential oil of *Allium macrostemon* bulbs and its two major constituents demonstrate strong larvicidal activity against *Aedes albopictus* mosquito larvae. The results suggested that the essential oil of *A. macrostemon* and the two major constituents may be recommended effectively in mosquito control, they also suggested further evaluation for safety in humans and to enhance their activity [30].

Rajkumar and Jebanesan, analysed essential oil obtained by steam distillation of leaves of *Clausena dentata*. Researcher observed the appearance of essential oil is colourless and a pleasant odour. The mean protection period of *Clausena dentata* essential oil at different concentrations against bite of *Aedes aegypti* was assessed by them. The results suggested that the organic solvent ethanol used in dilution of essential oil in protection period test did not showed positive irritant reaction. Both protection period and skin-irritant tests recommend essential oil could be used as natural repellent that prevent man-dengue vector contact [31].

Manzoor et al., investigated five essential oils from various parts of five plant species such as *Acorus calamus, Mentha arvensis, Ocimum basilicum, Saussrea lappa* and *Cymbopogan citratus* for their larvicidal property against *Aedes aegypti* (L.) and *Culex quinquefaciatus* (Say) larvae and their results are the highest larvicidal activity was documented in the essential oil from *O. basilicum* against *Ae. Aegypti* (L.) and *Cx. quinquefaciatus* (Say) with $LC_{50}$ values. Finally they concluded that essential oils had potential for controlling mosquito larvae [32].

Essential oil hydrolates of four plants such as *Zanthoxylum limonella, Zingiber officinale, Curcuma longa* and *Cymbopogon citratus* were evaluated for their larvicidal activity against two laboratory reared mosquito species - *Aedes albopictus* and *Culex quinquefasciatus*. The researcher revealed that the hydrolate of *Z. limonella* was most effective against both *Ae. albopictus* and *Cx. quinquefasciatus* with $LC_{50}$values. The larvicidal activity of hydrolates of *Z. officinale*, *C. longa* and *C. citratus* were also found promising with $LC_{50}$valuesagainst *Ae. albopictus* and *Cx. quinquefasciatus* [33].

Larvicidal bioassay carried out by Sarita Kumar et al., with the seed oil against early IV$^{th}$ instars of *Ae. aegypti* caused $LC_{50}$ and $LC_{90}$ values after an exposure to 24 hours. The larvicidal effect of the celery seed oil augmented by 1.2-fold; after an exposure to 48 hours; revealed $LC_{50}$ values. The seed oil did not cause immediate larval mortality; researchers suggested a delayed toxicity against the larval stage [34].

Larvicidal activity of essential oils from *Blumea mollis* [35] and *Zingifer officinalis* [36] has been reported against *Cx. quinquefasciatus*. Larvicidal activity of essential oils from *Melaleuca leucadendron*, *Litsea* cubeba and *Litsea salicifolia* [37], *Ocimum suave* and *O. kilimandscharicum* [38] have been reported against *Anopheles arabiensis, A. gambiae* and *Cx. quinqefasciatus*. Larvicidal activities of essential oils from *Zanthoxylum armatum* [39] and *Ocimum canum* [40] have been reported against *Cx. Quinquefasciatus, Ae. aegypti* and *An. Stephensi* [41].

Enan suggested that toxicity of constituents of essential oil is related to the octopaminergic nervous system of insects. Relatively few studies have been done on insecticidal activity or fumigant toxicity of caryophyllene oxide. Its high toxicity may result from the inhibition of the mitochondrial electron transport system because changes in the concentration of oxygen or carbon dioxide may affect respiration rate of insect, thus eliciting fumigant toxicity effects [42, 43]. Several reports indicate that essential oils and monoterpenoids cause insect mortality by inhibiting acetylcholinesterase enzyme (AChE) activity. Effects of furanocoumarins and pthalides isolated from *Angelica acutiloba Kitagawa var. sugiyame Hikino* against *Droshophila melanogaster* revealed the hypothesis that the insecticidal properties of the plant extracts are connected with the AChE (Acetylcholinesterase) inhibition [44].

Further studies on ethanolic extract from the fruits of *Pimpinella anisoides* V Brig. exhibited activity against AChE and BChE (Butyrylcholinesterase), with $IC_{50}$ values. The most abundant constituents of the extract were *trans*-anethole that exhibited the high activity against AChE and BChE with $IC_{50}$ values [45]. It is confirmed that the insecticidal activity of essential oils and/or mono terpenes is due to several mechanisms that affect multiple targets.

## III. CONCLUSION

The most attractive aspect of using essential oils and/or their constituents for pest control is their favorable mammalian toxicity because many essential oils and their constituents are commonly used as culinary herbs and spices and as medicines. It is found that the use of biopesticides will help in preventing the discarding of thousands of tons of pesticides on the earth and provide the residue free food and a safe environment to live [46]. The present review study shows a range of essential oils and phytochemicals from varieties of families that exhibit interesting insecticidal properties against several insects and pests [47].

Essential oils are complex mixtures of various molecules. Their biological effects might be either the result of a synergism of all molecules or could reflect only those of the main molecules. Almost literature cases analyses only the main constituents of essential oils. In that sense, for biological purposes, it could be more informative to study the entire oil rather than some of its components because the concept of synergism seems to be important.

Conclusion of our review study suggests that the development of natural or biological insecticides will help to decrease the negative effects of synthetic chemicals. Negative effects refer to residues in products and insect resistance. The utility of plant's essential oils and phytochemicals analysed by many research studies and also others support the Biopesticidal nature of the plant derived essential oils. These oils can be used as a cheap, eco-friendly safe and efficient alternative to the chemical larvicides.

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