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Review Article

Essential Oils as Green Repellents Against Mosquito Vectors

Katerina Atkovska[1], Stefan Kuvendziev[1], Erhan Mustafa[1], Mirko Marinkovski[1], Peyman Ghaffari[2], Kiril Lisichkov[1]

[1]*Faculty of Technology and Metallurgy, Skopje, University Ss. Cyril and Methodius, North Macedonia; klisickov@yahoo.com*

[2]*Chair of COST Action CA 16227*

Abstract: The mosquitoes are a serious threat to public health, since they are known vectors of many life-threatening diseases. Mosquito-borne diseases cause millions of deaths worldwide every year. While mosquitoes are important to maintain ecosystems, the aim is to keep them out of our personal space. People looking for alternatives to synthetic mosquito repellents may find that some natural repellents are effective in protecting them from bites. Natural insect repellents use natural ingredients such essential oils and other plant-based elements. Certain essential oils are effective and helpful in repelling mosquitoes, and are a natural alternative to the harsh chemicals in commercial bug sprays. These products are also likely to be less toxic to humans and the environment. Natural repellents and some essential oils may be effective in keeping mosquitoes away because they block their sense of smell. Many natural scents that are appealing to humans actually repel mosquitoes. Plant - based repellents are becoming more widely used as a protecting measure against mosquito bites, but more research is needed to develop natural repellents in terms of improving their repellent efficiency as well as in terms of their safety for use. This article presents a review about the best essential oils used as green repellents against mosquito bites, their efficiency, development and testing.

Key words: mosquito - borne diseases, plant-based repellents, essential oils.

INTRODUCTION

Mosquitoes are carriers, or vectors, for some of humanity's most deadly illnesses, and they are public enemy number one in the fight against global infectious disease. As a result of global economic trends and climate change, there is the possibility of intensifying vector populations, thereby increasing the number of persons infected by vector-borne diseases.

Vectors such as mosquitoes and ticks are cold-blooded and are particularly sensitive to climate factors. Global climate changes cause a big problem with the spread of mosquitoes. It can be said that the mosquitoes benefits from changes in the climate. Global warming has allowed mosquitoes, ticks and other disease-bearing insects to proliferate, adapt to different seasons, migrate and spread to new areas that have become warmer, areas where earlier they have never been detected. This means that more humans are exposed to viral infections such as Malaria, Dengue fever, Zika, West Nile fever, Yellow fever, and many more.

Repellency is an important way of preventing vector - borne diseases by reducing man - vector contact. Most commercially available repellents are prepared by using chemicals like DEET (N,N-Diethyl-meta-toluamide), DMP (dimethyl phthalate) and allethrin. But, these chemical repellents are not safe for public use because of their potential toxicity, they cause negative impact on the environment, have high operational cost. Therefore it is needful to develop environmentally friendly, long - lasting, low cost and preferably locally available repelling agents for mosquito control. The biologically active materials derived from the plant sources have been reported either as insecticides for killing larvae or adult mosquitoes, or as repellents for mosquito biting (Lee, 2018). They are generally more biodegradable, less hazardous and are one of the best alternatives for mosquito control.

Essential oil has been the active component of most important herbal remedies since ancient times. Many natural scents that are appealing to humans actually repel mosquitoes, including lavender, pepper-

mint, basil and eucalyptus. Essential oils are volatile naturally occurring, complex compounds, mixtures of hydrocarbons with a diversity of functional groups, characterized by a strong odor and are formed by plants as secondary metabolites. The metabolites like the monoterpenes such as - pinene, cineole, eugenol, limonene, terpinolene, citronellol, citronellal, camphor and thymol are the common constituents in a number of essential oils having mosquito repellent activity. Essential oils extracted from different families have shown high repellency against arthropod species (Lee, 2018; Mayura and Siriporn (2015)).

ESSENTIAL OILS AS MOSQUITO REPELLENTS

Lemon eucalyptus oil

PMD (para-menthane-3,8 diol) is a major repellent ingredient extracted from the leaves of lemon eucalyptus. It also can be chemically synthesized for use in commercial repellents. Citronellol, limonen and linalool are active compounds found in the extracts from eucalyptus, together with PMD. Oil of lemon eucalyptus extract or PMD is a plant-based ingredient that has been proven to prevent mosquito bites. Many plant extracts and oils show mosquito repellent activity but their effect lasts very short, from several minutes to several hours because their active ingredients are highly volatile, and after application they rapidly evaporate leaving the user unprotected. Unlike these active ingredients, PMD is highly effective and long-acting mosquito repellent, similar to DEET, because it has a lower vapor pressure than volatile monoterpenes found in most plant oils (Barasa, Ndiege, Lwande and Hassanali, (2002)). Environmental Protection Agency (EPA) has registered the lemon eucalyptus oil or PMD as a biopesticide repellent derived from natural materials in 2000 (Lee, 2018). Due to its proven clinical efficiency to prevent malaria and having no risk to human health, PMD has been recommended, by Centers for Disease Control (CDC), as the only plant - based repellent, for use in disease endemic areas (Emily Zielinski-Gutierrez and Roger (2010); EPA). A researchers from Australia in their study in 2014 have found that a formula containing 32% lemon eucalyptus oil provided at least 95% protection from mosquitoes for 3 hours (Frances , Rigby and Chow (2014)). In other two studies, led by Rodriguez, comparing the effect of different formulations on repellency of disease-carrying mosquitoes *Aedes albopictus* and *Aedes aegypti* when applied to participants hands, researchers found that a plant-based spray that contains oil of lemon eucalyptus, was the only DEET-free formula to deliver strong and long-lasting results (Rodriguez, Drake, Price and Hammond (2015); Rodrigez et al. 2017). Two different laboratory studies have confirmed that 20% PMD applied topically can provide 100% protection from *A. Stephensi* for 11 -12 hours and 100% protection for 2 hours against *Ae. Aegupty* (Trongtokit, Curtis and Rongsriyam (2005); Fradin and Day (2002)). (Table 1).

Table 1. Mosquito repellent efficiency of lemon eucalyptus oil

Plant	Other names	Active ingredients	Application	Repellency protection [%]	Type of study	References
Myrtaceae						
Corymba citriodora	lemon eucalyptus	citronellal PMD citronellol limonene geraniol isopulegol δ - pinene	20% PMD (1.7mg/cm2) applied topically	100% prot. for 11-12 h against A. stephensi	Laboratory study	Trongtokit, Curtis and Rongsriyam (2005)
			20% PMD applied topically	100% prot. against Ae. Aegypti for 120 minutes	Laboratory study	Fradin and Day (2002)
			30% PMD applied topically	96.88% prot. for 4 hours	Field study in Bolivia	Moore, Lenglet, and Hill (2002)

Citronella oil

Citronella oil is obtained from the leaves and stems of different species of the tropical island plants from the grass family. Essential oils and extracts belonging to plants in the citronella genus are commonly used as ingredients of plant-based mosquito repellents. Today, citronella is one of the most widely used natural repellents on the market. The efficiency of citronella-based repellents to deter mosquito biting lasts very short, about two hours, but the formulation of the repellent is also very important (Trongtokit, Rongsriyam, Komalamisra and Apiwathnasorn (2005); Goodyer, et al. 2010). Initially, citronella, containing citronellal, citronellol, geraniol, citral, α pinene, and limonene, shows similar effectiveness as DEET, but the oil rapidly evaporate causing loss of efficiency and leaving the user unprotected. Citronella oil, only contains trace quantities of naturally occurring constituent PMD (para-menthane-3,8-diol), which is primarily responsible for the efficiency for repelling biting insects and other arthropods. Trongtokit and his coworkers have shown that the topical application of 100% citronella can provide complete protection against three mosquito species (*Ae. aegipty, C. quinquefasciatus* and *A. dirus*) for a particular time in a laboratory setting (Trongtokit et al. (2005). Another research team have tested the repellency protection of the citronella essential oil (*Cymbopogon winterianus)* against the same three mosquito species and the results are given in the Table 2.

Table 2. Mosquito repellent efficiency of citronella oil

Plant	Other names	Active ingredients	Application	Repellency protection [%]	Type of study	References
Poaceae						
Cymbopogon spp.						
C. nardus	citronella	citronellal	100% ess. oil applied topically	100% prot. against *Ae. aegupty* for 120 min., 100% prot. against *C. quinquefasciatus* for 100 min., 100% prot. against *An. dirus* for 70 min	laboratory study	(Trongtokit, Rongsriyam, Komalamisra and Apiwathnasorn (2005)
				100% prot. for 7-8h against *An.stephensi*	laboratory study	Tawatsin, Wratten, Scott, Thavara and Techadamrongsin (2001)
			40% ess. oil applied topically			
C. winterianus			100% ess. oil applied topically	100% prot. against *A. aegypti* for 3h, 100% prot. against *C. quinquefasciatus* for 8 h, 100% prot. against *An. dirus* for 3.5 h	laboratory study	Tawatsin, Wratten, Scott, Thavara and Techadamrongsin (2001)
C. citratus	lemongrass oil grass	citral α-pinene	100% ess. oil applied topically	74% prot. against *An. darlingi* for 2.5h and 95% prot. against *Mansonia* spp. for 2.5h	field study in Bolivia	Moore, Hill, Ruiz and Cameron (2007)

Clove oil

Clove oil has been widely used in food, cosmetics and medicine and in insects repellents as well. Clove oil distilled from *Syzygium aromaticum*, was reported as the most effective mosquito repellent in the comparison with other essential oils made by some researchers. They showed that this oil gave 90 to 225

min of protection against *Ae. aegypti* and 75 to 213 min of protection against *An. albimanus* depending on oil concentration (Barnard, 1999). Another research team performing laboratory study proved that applying 100% clove oil topically can provide 100% protection for 120 min., 240 min., and 210 min., against *Ae. aegypti*, *C. quinquefasciatus* and *An. dirus*, respectively (Trongtokit et al. (2005)). The comparison of two different laboratory test results is given in the Table 3 and indicate that a topical solution of 100% clove oil could provide 100% efficiency at blocking some mosquitoes for between 120 and 225 minutes. The major constituents of clove oil are eugenol, eugenol- acetate and beta-caryophyllene. As far as safety is concerned, the same study found that clove's active ingredient, eugenol, could be safely used at around a 0.5% concentration. Higher concentrations may be generally safe also, but users risk skin irritation if they choose to use clove oil topically.

Table 3. Mosquito repellent efficiency of clove oil

Plant	Other names	Active ingredients	Application	Repellency protection [%]	Type of study	References
Myrtaceae						
Syzygium aromaticum	clove	eugenol eugenol acetate β-caryophyllene carvacrol thymol cinnamaldehyde	100% ess. oil applied topically	100% prot. against *Ae. aegypti* for 225 minutes 100% prot. against *An. albimanus* for 213 minutes	laboratory study	Barnard 1999
			100% ess. oil applied topically	100% prot. against *Ae. aegypti* for 120 min. 100% prot. against *C. quinquefasciatus* for 240 min. 100% prot. against *An. dirus* for 210 min.	laboratory study	Trongtokit, Rongsriyam, Komalamisra and Apiwathnasorn (2005)

Peppermint oil

Peppermint oil extracted by steam distillation from the leaves of *Mentha piperita* has a long tradition of medicinal use. It has high menthol content and also contains menthone and menthyl acetate. Menthone, present in high concentration in peppermint oil, is reported to act as a natural pesticide. Because of increased interest in developing plant origin insecticides as an alternative to chemical insecticide, the availability, low budget and less environmental impact, there are studies undertaken to assess the larvicidal and repellent potential of the essential oil of peppermint plant, *M. piperita* against larva of these three mosquito species (*Aedes aegypti*, *Anopheles stephensi* and *Culex quinquefasciatus),* and adult stages of these three species (*Anopheles annularis, Anopheles culicifacies* and *Culex quinquefasciatus*) (Ansari, Padma, Mamta and Razdan (2000)). The oil has shown strong repellent action against adult mosquitoes when applied on human skin. The results are given in the Table 4 and it shows that percent protection obtained against first specie is 100% for 11 hours, for second one it is 92.3% for 8 h, and for the last one the protection percentage is 84.5 for 8h. This study has shown that peppermint oil has also the larvicidal activity against different species of mosquitoes and can be used selectively in places where water is stagnant. Sarita and his colleagues found that peppermint essential oil was effective against mosquito larvae and provided 100% protection against bites from adult dengue fever mosquitoes (*Ae. aegypti*) for up to 150 minutes (Sarita, Naim and Radhika (2011)).

Table 4. Mosquito repellent efficiency of peppermint oil

Plant	Other names	Active ingredients	Application	Repellency protection [%]	Type of study	References
Lamiaceae						
Mentha piperita	peppermint	menthol menthone menthyl acetate	100% ess. oil applied topically	100% prot. against *An. annularis* for 11 h 92.3% prot. against *An. culicifacies* for 8h 84.5% prot. against C. quinquefasciatus for 8 h	field study	Ansari, Padma, Mamta and Razdan (2000)
			application of 3ml/m^2 of water surface	100% mortality for C. quinquefasciatus within 24h 90% mortality for Ae. aegypti withih 24h 85% mortality for An. stephensi within 24h	laboratory study	
			100% ess.oil applied topically	100% prot. against *Ae. aegypti* for 150 min.	field study	Sarita, Naim and Radhika (2011)
			100% ess.oil applied topically	100% prot. against *Ae. aegypti* for 45 min.	laboratory study	Barnard 1999

Immortelle oil

Immortelle essential oil is distilled from the flowering tops of the plant *Helichrysum italicum*. This essential oil is effective as wound healing agent and for healing several skin disorders. There are several studies that have investigated the larvicidal potential of immortelle oil against some mosquito species. Laboratory bioassays on insecticidal activity of essential oils extracted from six Mediterranean plants have been carried out against the larvae of the mosquito *Aedes albopictus* by Barbara Conti and the colleagues (Conti, Canale, Bertoli, Gozzini and Pistelli (2010)). They have also investigated the chemical composition of the six essential oils. It was proved that different mortality responses are a function of both oil type and dosage rate. The results from this study has shown that immortelle oil from *H. italicum* **has** significant amounts of oxygenated monoterpenes and the highest level of sesquiterpenes (Neril acetate, α - Pinene, Limonene, γ-Curcumene, Neril propionate and Nerol). At the highest dosage of 300 ppm, immortelle oil from *H. italicum*, has showed a higher mortality than the other oils, with 100% mortality rate (Table 5).

Table 5. Mosquito repellent efficiency of immortelle oil

Plant	Other names	Active ingredients	Application	Repellency protection [%]	Type of study	References
Asteraceae						
Helichrysum italicum	immortelle	neryl acetate α-pinene limonene γ--curcumene neril propionate nerol	dosage rate of 200 ppm	41.7% mortality for *Ae. albopictus* within 24h	laboratory study	Conti, Canale, Bertoli, Gozzini and Pistelli (2010)
			dosage rate of 250 ppm	81.7% mortality for *Ae. albopictus* within 24h		
			dosage rate of 300 ppm	100% mortality for *Ae. albopictus* within 24h		

Lemongrass oil

Lemongrass, scientifically known as *Cymbopogon citratus* is an herb with a subtle citrus flavor. One study found that topical application of lemongrass essential oil provided 74–95% protection for 2.5 hours against two types of mosquito during a field study (Moore, Hill, Ruiz and Cameron (2007)). Mayura and Siriporn investigated the repellent efficiency of mixtures of different essential oils and showed that a combination of lemongrass essential oil and olive oil provided 98.8% protection and the combination of lemongrass and coconut oils showed 98.9 % protection against the two species of mosquito (*Ae. aegypti* and *C. quinquefasciatus*) (Mayura and Siriporn (2015)). The results of these research works are given in Table 6.

Table 6. Mosquito repellent efficiency of lemongrass oil

Plant	Other names	Active ingredients	Application	Repellency protection [%]	Type of study	References
Poaceae						
Cymbopogon citratus	lemongrass	citral α-pinene	topically	74% prot. against *An. darlingi* for 2.5h 95% prot. against *Mansonia* spp. for 2.5 hours	field study in Bolivia	Moore, Hill, Ruiz and Cameron (2007)
			topically lemongrass oil + olive oil	98.8% prot. against *Ae. aegypti* for 60 min. and *C. quinquefasciatus for 170 min*	laboratory study	Mayura and Siriporn (2015)
			topically lemongrass oil + coconut oil	98.9% prot. against *Ae. aegypti* for 85 min. and *C. quinquefasciatus for 115 min*		

Basil oil

Basil (Ocimum basilicum) is a common ingredient in many cuisines, but it may also be a moderately effective mosquito repellent. There are several studies testing basil as a repellent. Some field studies in Kenya found that just the potted plant can provide nearly 40% protection against a type of mosquito that can carry malaria (*An. gambiae*) (Seyoum, Kabiru, Lwande, Killeen, Hassanali and Knols (2002); Seyoum, Killeen, Kabiru, Knols and Hassanali (2003)). The study of Adam and the associates aimed to evaluate the repellent activity of essential oil extracted from *O. basilicum* and to formulate cream repellent for mosquitoes from this essential oil (Almardi, Salma, Thana, Rasha, Salma and Omer (2019)). Major compounds in the investigated basil oil were linalool, cinnamic acid and eucalyptol. In this work, the oil was assessed for topical repellence effects against malarial vector *Anopheles* mosquito in cages. The essential oil was tested at three different concentrations 2, 4 and 6% of the oil. From the results obtained, the essential oil of *Ocimum basilicum* exhibited relatively high repellency effect (> 250 minutes at 6% concentration). Tawatsin and others in their work have investigated the repellent efficiency of the basil oil of *Ocimum americanum* (Tawatsin, Wratten, Scott, Thavara and Techadamrongsin (2001)). They have found that this essential oil provides 100% efficiency for 3h, 3.5h and 8h against *Ae. aegipty, A. dirus* and *C. quinquefasciatus*, respectively (Table 7).

Table 7. Mosquito repellent efficiency of basil oil

Plant	Other names	Active ingredients	Application	Repellency protection [%]	Type of study	References
Lamiaceae						
Ocimum americanum	basil	p-cymene estragosl linalool linoleic acid eucalyptol eugenol camphor citral thujone limonene ocimene	potted plant potted plant 100% ess. oil applied topically	39.7% protection against *An. gambiae* 37.9% protection against *An. gambiae* 100% prot. against *A. aegypti* for 3h, 100% prot. against *C. quinquefasciatus* for 8 h, 100% prot. against *An. dirus* for 3.5 h	semi-field study in Kenia field study in Kenia laboratory study	Seyoum, Kabiru, Lwande, Killeen, Hassanali and Knols (2002) Seyoum, Killeen, Kabiru, Knols and Hassanali (2003) Tawatsin, Wratten, Scott, Thavara and Techadamrongsin (2001)
Ocimum basilicum	basil	linalool cinnamic acid eucalyptol α - citral eugenol	2% ess. oil applied topically 4% ess.oil applied topically 6% ess. oil applied topically	125 min. prot. against *Anopheles* 200 min. prot. against *Anopheles* 270 min. prot. against *Anopheles*	laboratory study	Almardi, Salma, Thana, Rasha, Salma and Omer (2019)

INCREASE IN EFFICIENCY OF ESSENTIAL OILS REPELLENTS

The application of plant-based repellents is increasing due to the fact that consumers want to protect themselves from mosquito bites but at the same time to use products that do not have a detrimental effect on them and on the environment. Considering that essential oils are highly volatile, evaporate quickly and leave the user unprotected, the biggest challenge in applying essential oil-derived repellents is to increase their effectiveness and extending their longevity. Aiming to that, many researchers work to develop methods that will make this possible.

Synergistic interaction

Combination of several essential oils from different plants which lead to synergistic effect, is one of the most used methods for improvement of the repellent efficiency. The synergistic interaction of a mixture of active compounds from different essential oils provides a higher effectiveness of the repellents, compared to the sum of the efficiencies that each component has individually. Das and his associates have investigated the synergistic mosquito-repellent activity of *Curcuma longa*, *Pogostemon heyneanus* and *Zanthoxylum limonella* essential oils (Das, Dhiman, Talukdar, Rabha, Goswami and Veer (2015)). Their work shows that at an optimum concentration of 20%, the essential oils of *C. longa*, *Z. limonella* and *P. heyneanus* provided complete protection time of 96.2, 91.4 and 123.4 min, respectively, against *Aedes albopictus* mosquitoes in the laboratory. The 1:1:2 mixture of the essential oils provided 329.4 and 391.0 min of CPT in the laboratory and field trials, respectively. Another research group has evaluated synergistic effect of different combinations of ten essential oils against *Aedes aegypti*. In the study of protection period, litsea

+ rosewood in the ratio of 1:1 (v/v) at 10% concentration showed 86% repellency for 4 hours against this vector of dengue and chikungunya (Uniyal et al. 2015). Three most toxic essential oils (Manuka, oregano, and clove bud essential oils) were examined for their chemical composition and combined toxicity against *Ae. aegypti* larvae. This results revealed a synergistic interaction between Manuka and oregano essential oils and an antagonistic interaction between Manuka and clove bud essential oils (Muturi, Ramirez, Doll and Bowman (2017)). Other study was designed to compare the behavioral responses of *Aedes aegypti* to a single essential oil and to a mixture of two or three essential oils. Mixtures were prepared from essential oils extracted from *Litsea cubeba* (LC), *Litsea salicifolia* (LS), and *Melaleuca leucadendron* (ML). Greater contact irritancy was seen from mixed oils of LC and LS than with other mixed oils. Mixtures of LC and LS at 0.075% showed the highest synergistic action (65.5% escaped) compared to that with unmixed oil alone at the same concentration (LC=20% and LS=32.2%). In addition, mixtures of LC and LS at 0.075% demonstrated the highest non-contact repellency (62.7%) and showed a greater effect than the use of LC (20%) or LS (20.3%) alone (Noosidum, Chareonviriyaphap and Chandrapatya (2014)).

Formulation technology development

Essential oils derived from different plants show significant mosquito repellent activity. But as mentioned earlier, due to the high volatility of the active phase, the repellent effects rapidly diminish. The duration of protection time can be improved via formulation technology development, by retaining the active components on the skin for longer periods. Improving the effectiveness of the repellent can be achieved by applying cream-based formulations and polymer mixture-based formulations. Ointment and cream formulations of lemongrass oil in different classes of base and the oil in liquid paraffin solution have been evaluated for mosquito repellency in a topical application. Base properties of the lemongrass oil formulations influenced their effectiveness. The oil demonstrated efficacy from the different bases in the order of hydrophilic base > emulsion base > oleaginous base. This study showed that the mosquito bite-deterrent effect of 15%v/w hydrophilic ointment formulation of the oil is very promising for topical use (Oyedele, Gbolade, Sosan, Adewoyin, Soyelu and Orafidiya (2002)). Another study was conducted to determine the mosquito repellent activities of some selected plant materials in order to obtain safe and efficient herbal mosquito repellent formulations by combinations of the selected plant materials. It showed that plant essential oils showed higher mosquito repellent activities compared to plant extracts. In order to obtain the products with improved repellent efficiency, two herbal mosquito repellent formulations have been made, using highly volatile essential oils together with herbal extracts. The prepared mosquito repellent gel and the mosquito repellent spray which contained 16% (V/V%) total active ingredients each, showed 100% mosquito repellency for outdoor and indoor field trials which were carried out for six hours each day for two days (Ranasinghe, Arambewela and Samarasinghe (2016)). Citronella essential oil has been reported as an excellent mosquito repellent, but because of the irritant nature and rapid volatility, its topical application is limited. Yadav and others in their study reported a novel approach to develop a mosquito repellent cream formulation of citronella oil using phase inversion temperature technique and evaluating the cream by texture analyzer for firmness/hardness, spreadability, and extrudability. Safe and effective mosquito repellent cream formulation of CEO was successfully developed (Yadav et al. 2014).

Microencapsulation, fixative agents, nanotechnology

Microencapsulation is another way to improve the efficiency of the essential oils repellency. It resulted with sustained release properties and long-lasting repellency of the encapsulated oil. A research work has shown that increased repellent efficacy was achieved by microencapsulation of thyme oil (Chung, Seo,

Lim, Park, Yea and Park (2013)). It is also not uncommon to use fixative agents to increase the effectiveness of essential oil based repellents. The most widely used fixative agents for this purpose are vanillin, salicyluric acid and paraffin. Adding vanillin in citronella oil and *Zanthoxylum piperitum* oil has extended their protection time to 4.8h and 2.5 h, respectively (Chung et al. 2013). The development of nanotechnology has enabled it to be applied in the field of preparation of effective plant based repellents. The biosynthesis of silver nanoparticles using *Quisqualis indica* has given good results in improving efficiency against malaria an Zika virus mosquito vectors. (Govindarajan, Vijayan, Kadaikunnan, Alharbi and Benelli (2016)).

CONCLUSION

Due to the possible harmful effects on human health and the environment, synthetic repellents against arthropods, are increasingly being replaced by plant-based repellents. Studies in recent decades show that plant essential oils can be considered a viable alternative to synthetic repellents. Increasing the repellent efficiency as well as extending the duration of protection time of natural repellents are the main challenges in the technology of development of natural repellents. The progress in the field of biotechnology, nanotechnology and formulation technology can enable the development of essential oil-based repellents that have the aforementioned properties. This paper is intended to attract the attention of entomologists and people in the field of mosquito-borne diseases, to understand the potential use of essential oils as green repellents against mosquito vectors.

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