Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2023; 11(1): 177-184

Received: 28-11-2022
Accepted: 02-01-2023

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Investigation of the efficacy of essential oils used in pest control

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DOI: https://doi.org/10.22271/j.ento.2023.v11.i1c.9154

Abstract
Due to the negative effects of chemicals used on human and environmental health in recent years, alternative methods have been started to be used in the control against pests. At the beginning of these alternative methods is the use of essential oils in the pest management. Essential oils are biodegradable, species-specific, side-effect-free components that do not threaten human, animal and environmental health. Essential oils, as a rule, have a low molecular weight. Essential oils are produced from almost all plant organs, including roots, stems, leaves, fruits, flowers, seeds and tree bark.
The purpose of this review is to investigate the effectiveness of essential oils used in the control against pests.
In the study, essential oils obtained from species belonging to the Lamiaceae family, the general properties of essential oils with a repellent effect against pests, plant essential oils (EO), which are among the biologically active components, the possibilities of their use in decontaminating pests were discussed.
This review will shed light on future studies on the development of alternative products to chemicals used in the pest management.

Keywords: Pests, ınsects, essential oils, repellent effect

1. Introduction
Essential oils are components that are biodegradable, species-specific, have no side effects, and do not threaten human, animal and environmental health (Al-Amin, 2020) [1]. When essential oils were examined in terms of antibacterial activity, it was determined that a mixture of thyme, clove, coriander and cinnamon showed the most antibacterial activity, followed by a mixture of thyme, mint, rosemary, mustard, coriander and sage (Burt, 2004) [11].
When the data of the last 50 years are examined, it is seen that especially chemicals (eg Dimethoate and Fenthion) are used in the control of pests (Skouras *et al*. 2007; Daane and Johnson 2010) [50, 17]. However, due to the negative effects of the chemicals used on human and environmental health, alternative methods have been started to be used pest control in recent years. One of these alternative methods has been the use of pyrethroids (Margaritopoulos *et al*. 2008) [35].
Plant essential oils (EO), which are among the biologically active components, are components with ecotoxicological properties that are used to reduce the negative effects by pests (Benelli *et al*., 2012) [9].
In this review, the properties of essential oils that have a repellent effect against pests and important plant species used as essential oils are mentioned.

2. General properties of essential oils with repellant effect against pests
Essential oils generally have a low molecular weight. It is lipophilic and volatile at room temperature. Essential oils are known as essential oils; it is produced from almost all plant organs, including roots, stems, leaves, fruits, flowers, seeds and bark (Dhifi *et al*. 2016) [20]. Essential oils are used in various fields such as perfumery, cosmetics, drugs and food protection (Perricone *et al*. 2015) [41]. Textile products that have a repellent effect against insects (nets, curtains, clothes, military uniforms, textiles used around the home, etc.) provide protection against disease-causing vectors such as mosquitoes and ticks.
The repellent effect of these textile products are based on the inclusion of insect repellent compounds. Insect repellent compounds; it is divided into synthetic and natural.

Natural ingredients; citronella grass, lemongrass, rosemary, mint, basil, tea tree, neem tree, lavender, thyme, lemon eucalyptus, clove and cinnamon. Some of the synthetic components are; permethrin compounds are allethrin, malathion, DEET, DETA, IR3535 and picaridin. The insecticidal effectiveness of pure natural compounds is very low due to their properties. In order to increase the insecticidal effectiveness of these compounds, essential oils are used by encapsulation and combined with other synthetic compounds used for pest control.

Mosquitoes are among the important insect species that threaten human health. It is also the vector of many diseases that cause death, such as encephalitis, filariasis and malaria, which transmit a number of diseases such as dengue fever, chikungunya, Japanese B. To prevent these diseases, personal protection against mosquitoes is important. Essential oils obtained from plants, which are used as an alternative to insecticides, are also used for this purpose.

Essential oils are volatile mixtures of hydrocarbons. With this; has various functional groups and their repellent properties; due to the presence of mono terpenes and sesquiterpenes. Essential oils obtained from different plants; monoterpenes such as α-pinene, cineole, eugenol, limonene, terpinolene, citronellol, citronellal, camphor, and thymol (Yared, 2020) [62]. In some cases, these herbal essential oils; by working synergistically with chemicals, it increases the effectiveness of the chemical. Essential oils used to repel insects; It is applied to human skin, clothing and similar surfaces. The most widely used insect repellents in recent years are N, N - diethyl -3- methylbenzamide and DEET. However, as a result of the researches, negative effects of these substances on human and environmental health have been observed. Therefore, studies on the use of natural plant-based insecticides, which are environmentally friendly and biodegradable, have begun (Al-Amin, 2020) [1]. In a study conducted; to combat Varroajacobsoni (Acari: Varroidae) mites found in honey bee colonies, a linalool (chemical component) was created by mixing thymol (thyme essential oil), eucalyptus oil and menthol (peppermint oil). As a result of the study, the mortality rate in the mite population, which was applied thymol-based mixture, was determined as 96.7% and as 4.4% in the control (Yared, 2020) [62].

3. Essential oils obtained from species belonging to the *Lamiaceae* fam

In a study conducted by Conti *et al*. in 2011 [16], *Lavandula angustifolia* and *Rosmarinus officinalis* L. essential oils were found to have toxic effects in fumigation tests against A. *albopictus, Musco domestica, Fungus sciarid Lycoriella, Ceratitis capitata.*

Pavlidou *et al*. (2004) [40] found that essential oils extracted from *Salvia fruticosa* and *Mentha pulegium* L. had a toxic effect on the larvae of *B. oleae*. In addition, extracts obtained from the fruit, leaves and shoots of *Citrus aurantium* (L.) have been reported to have insecticidal activity against *B. oleae* (Siskos *et al*. 2007; Siskos *et al*. 2009) [48]. In a study, the toxicity of *Bactrocera oleae*, which is an olive pest, as a result of feeding with essential oils obtained from *Hyptis suaveolens*, rosemary (*Rosmarinus officinalis)* and lavender (*Lavandula angustifolia*) species was investigated. This study was run in laboratory conditions and mortality rates were found to vary from 12% (EO concentration: 0.01% w: v) to 100% (EO concentration: 1.75% w: v). However, when all essential oils were applied at a concentration of 1.75%, essential oils from L. *angustifolia* and *H. suaveolens* species were reported to cause 60% more mortality.

A. *Pseudodictamnus* B. *Mentha longifolia* C. *Leonotis leonurus* D. *L. Ocymifolia* E. *Salvia africana*

F. *S. Aurea* G. *S. Chamealaeagnea* H. *S. Dentata* I. *S. Stenophylla* J. *Stachys aetiopica*

K. *S. Linearis* L. *S.rugosa* M. *Tetradenia riparia* N. *Teuricum africanum* O. *T. trifidum*

Fig 1: Some species belonging to the *Lamiaceae* fam. All photographs taken by B.-E. Van Wyk.

The essential oils of *Hyptis suaveolens*, rosemary (*Rosmarinus officinalis*) and lavender (*Lavandula angustifolia*) species were analyzed by Gas Chromatography-Electron Effect Mass Spectrometry. As a result of the analysis, it was determined that the monoterpene and sesquiterpene hydrocarbons of the essential oils of the *H. suaveolens* species were more dominant. Oxygenated monoterpenes were found to be effective in essential oils of R. *officinalis* and *L. Angustifolia* species. A study examined the repellent effects of peppermint (*Mentha piperita*) and lavender oil against pests. As a result of the study, it was determined that peppermint and lavender essential oils were effective against *M. domestica* (Kamari, 2022) [29].

In another study by Barbara Conti (2011), they reported that oils obtained from Mediterranean plants (*Achillea millefolium, Lavandula angustifolia, Helichrysum italicum, Foeniculum vulgare, Myrtus communis* and *Rosmarinus officinalis*) have insecticidal activity against mosquito (*Aedes albopictus*) species (Phasomkusolsil, 2010) [43]. In the study by Jason *et al*. The repellent properties of lemon eucalyptus, geranium and lavender oils against *Ixodes ricinus* (Acari: Ixodidae) species were investigated in laboratory and field conditions. As a result of the study, it was determined that the mentioned oils were 100% effective when diluted 30% in 1, 2-propanediol (Skaria, 2006) [49].

3.1 Lavender oil (*Lavandula angustifolia*)

Lavandula angustifolia is a species of the Lamiaceae family. Lavandula angustifolia oil has antibacterial, repellent properties against fungal diseases and pests. The main components of this oil are; linalool (26-44%), 1, 8-cineol (≤36%), camphor (≤15.3%) and borneol (≤4.9%). Linalool is recognized as the main ingredient responsible for the insect repellent effects of lavender oil (Erland, 2016) [25].

Kheloul *et al*. with the work done by; It has been proven that lavender essential oil has a repellent effect of 85.7% against *Culex quinquefasciatus* and 100% against *Aedes aegypti*, *Anopheles sfttephens* (da Silva, 2020).

Lavender, also known as Lavandula angustifolia (*Lamiaceae*), is an evergreen, perennial herb. It grows up to 1 meter in length. Lavender is one of the plants used for medicinal and aromatic purposes. In addition, lavender oil is used in aromatherapy to treat anxiety, nervousness, mental stress, insomnia and burnout syndrome. Lavender oil is also an antiseptic and can be used for disinfection of wounds. It can also be used effectively in the treatment of alopecia areata, fungal infections, acne and eczema treatment, and stomach disorders (Kaur, 2021) [28].

3.2 Rosemary oil (*Rosmarinus officinalis*)

Rosemary (*Rosmarinus officinalis*) essential oil is mostly harvested from the fresh blooming tops of the plant and distilled by steam distillation. The main active volatile compounds in rosemary oil; 1, 8-cineol (eucalyptol, 24.6%), α-pinene (17.7%), camphor (12.4%) and camphene (11.3%). Due to the use of rosemary in foods, it is thought to have a minimum toxic effect, reports that it does not show any allergic reactions in humans (Baker, 2022) [6].

Rosemary oil has been shown to provide 100% repellent protection for up to 8 hours against *Culex quinquefasciatus* (mosquito) and adults of *Anopheles stephensi* (da Silva, 2020). In another study, it was determined that Rosemary oil provided a 100% repellent effect against *Aedes aegypti* for up to 90 minutes. In addition, it has been determined that rosemary oil has a high amount of toxic effect against the first instar larvae of this mosquito species. Caballero-Gallardo *et al*. (2021) [13] showed that rosemary oil and citronella essential oil had a repellent effect against *Ulomoides dermestoides*.

3.3 Peppermint oil (*Mentha piperita* L.)

Mentha piperita L. is a perennial herb with a height of 30-90 cm. Peppermint oil is used in cosmetics, food and pharmaceutical industries. It is also used in personal care products (toothpaste, tropical preparations, mouthwashes), aromatherapy (treatment of bronchitis, bacillary dysentery, diabetes, diarrhea, dysmenorrhea, fever, hypertension, jaundice, nausea, pain, and respiratory and urinary tract infections) (Olorunnisola, 2014) [51].

Active components of peppermint oil; Menthone is p-Mentan-3, 8-diol. Peppermint oil has been actively used to repel mosquitoes for many years. Active volatile components of peppermint (Mentha × Piperita) essential oil; menthol (35.21%), menthone (21.56%), menthyl acetate (6.90%), piperitone (5.60%), limonene (5.40%), and 1, 8-cineol (5.30%) (Badea, 2019) [7]. Although peppermint essential oil has not been proven to be the most effective repellant against pests, it has been found to have a moderate repellent effect (Palermo, 2021) [39]. On the other hand, Palermo *et al*. (2021) [39] has proven that peppermint essential oil has a moderate repellent effect against mealybug (*Tribolium*). It has been determined that peppermint oil has a 100% repellant effect against *Musca domestica* (Chauhan *et al*., 2018) [12]. In a study by Sarita Kumar *et al*., (2018), peppermint oil proved to

have an outstanding repellent activity against *Aedes aegypti* (Chauhan *et al*., 2018) [12]. In another study by Ansari *et al*. (1994), peppermint oil; It was found that when *Aedes aegypti* (92.3%) *Anopheles stephensi* (84.5%) and *Culex quinquefasciatus* (100%) were applied against different mosquito species, it showed a very strong repellent effect (Jovanovic, 2020).

3.4 Basil Oil (*Ocimum tenuiflorum*)

Active volatile components of basil oil (*Ocimum tenuiflorum*); eugenol (1.94–60.20%), methyl eugenol (0.87–82.98%), β-caryophyllene (4.13–44.60%), and β-element (0.76–32%, 41) is. The repellent effect of this oil against pests is due to the active volatile component of eugenol (Raina, 2013) [44]. Eugenol content of basil; it varies depending on the differences in harvest time and the variety of basil. In addition, it has been determined by studies that basil oil has a preventive effect on fungal diseases (Tangpao, 2018) [54]. Studies have shown that basil oil has a 100% repellent effect against *Aedes aegypti* pest, but it has been shown to have an attractive effect against species such as *Apis mellifera* (Tan, 2012) [53].

3.5 Tea Tree Oil (*Melaleuca alternifolia*)

Melaleuca alternifolia is a medicinal plant in Australia. The main components of the oil; terpene 4-ol (>40%), γ-terpinene (>20%), α-terpinene (>9.0%), 1, 8-cineole, limonene, ρ-Cymene, α-Pinene and α-terpineol (Shrestha, 2017) [47]. Studies have shown that *Melaleuca alternifolia* species provides 78% protection against *Aedes aegypti* (da Silva, 2020). According to Maguranyi *et al*. (2009) [37] with the work done by tea tree oil; it has proven to be one of the most effective essential oils against *Aedes aegypti*, *Culex annulirostris* and *Culex quinquefasciatus* (Maguranyi *et al*. 2009) [37].

3.6 Oregano Oil (Thymus)

Thyme grows in sunny, sloping, hilly areas surrounding the Mediterranean. Thyme exporting countries; Turkey, Greece and Mexico. The taste of thyme is sharp, spicy, slightly bitter (Farrell, 1990). The active compound responsible for the repellent and insecticidal effects of the essential oil obtained from the thyme plant is thymol (40.5%). Other main compounds are p-cymene (23.6%), carvacrol (3.2%), linalool (5.4%), β-caryophyllene (2.6%), terpinen-4-ol (0.7%), borneol, 1, 8-cineole, geraniol, various other terpenoids, alcohols and esters (Baker, 2022) [6]. Studies have proven that thyme oil has a repellent effect for up to 3 hours against harmful insect species (Agnihotri, 2018) [3]. In the studies carried out; thyme oil has been shown to exert a repellent effect against *Bemisia tabaci*, *Aedes aegypti*, *Sitophilus zeamais* and *Plodia interpunctella* (Kim, 2012) [31]. The use of thyme oil and thyme hydrosol at the rates of 0.05%, 0.1% and 0.3%; in a study examining the effects on the physicochemical, microbiological and sensory properties of green olives (*Edremit olive variety*) fermentation; it has been determined that the pH values of the brined olives to which thyme oil is added are higher, the highest acidity and the highest sensory values are seen in the thyme hydrosol (Farrell, 1990).

3.7 Neem Oil (*Azadirachta indica*)

Neem tree (*Azadirachta indica*) is a tropical tree of the *Meliaceae* family that can reach 30 meters in height. It has a rough and hard shell structure. The active ingredients of neem oil are; Azadirachtin, Nimbin, Nimbidin, Nimbidol, Sodium nimbinate, Gedunin, Salannin, Quercetin (Veiga, 2019) [58]. In India, neem oil is known as the "village pharmacy"; it has been used for years in Ayurvedic medicine, especially in India, due to its healing properties (Ricardo, 2021) [45]. Neem oil has properties such as antiseptic, antiviral, antipyretic, anti-inflammatory, anti-ulcer, anti-fungal (Ahsaei, 2020) [2]. It is a natural repellent compound known as neem oil (*Azadirachta indica*). It is also a natural alternative to DEET used as a chemical pesticide (Agnihotri, 2018) [3]. Neem oil is a highly effective ingredient against many types of pests. Azadirachtin obtained from the seeds of the neem plant, neem oil is the main component in it (Caputo, 2020).

Azadirachtin is a mixture of 7 isomers; it is the main component of neem oil responsible for pest control (Kumar, 2018) [33]. Studies have shown that neem oil is moderately effective against *Anopheles* and *Aedes albopictus* species, while it is 100% effective against Asian tiger mosquitoes. *Azadirachata indica*, obtained from the leaves and flowers of neem oil, is a natural pesticide. It has also been used for centuries to control pests and diseases. Neem oil; It contains triglycerides and many triterpenoids. Azadirachtin obtained from neem oil is the most active ingredient for repelling and pest control. Neem oil is used as an important weapon against malaria due to its insect repellent properties.

In a study conducted in Delhi Malaria Research Center in 1994; It has been determined that when 1% neem oil is added to kerosene, it protects people against mosquitoes, *Anopheles species* (malaria) and *culex*.

In a study, it was found that when coconut oil and neem oil are mixed and used on the human body, protection is provided by *Anopheles* (malaria vector) for 12 hours (Nguyen, 2021) [34].

In another study conducted by V. P. Sharma in laboratory and field conditions; A mixture of 2% neem oil with coconut oil and mustard oil helps *Phlebotomus argentipes*; it has been determined that it has a repellent effect against *Phlebotomus papatasi*. It has been observed that this mixture has 85% effectiveness against *Anopheline*, 37.5% *Aedes*, and 61-94% against *Culex species*. As a result, it is recommended to use Neem oil as a protection against mosquitoes. In addition, Neem oil is effectively used against pests such as insects, mites, ticks and nematodes.

3.8 Lemongrass Oil (Cymbopogon flexuosus)

Another natural compound is lemongrass oil. Various types of lemongrass are available; *Cymbopogon flexuosus* (red grass) is a commercially grown lemongrass species. The essential oil obtained from this variety shows higher solubility, especially in alcohol; which makes it of higher commercial importance. Lemongrass essential oil, small amounts of linalool, geraniol, citronellol, nerol, 1,8 cineole, citronellal, linalyl acetate, geranyl acetate, apinene, limonene, caryophyllene, b-pinene, b-thujene, myrcene, b-ocimene, terpinolene, It contains 75% to 80% citral together with methyl heptanone, and α-terpineol (Skaria, 2006) [49].

These compounds also contribute to the antibacterial properties of lemongrass oil. Lemongrass oil has broad-spectrum antifungal properties in fungi such as *Candidia spp* (Olorunnisola, 2014) [51]. In a study conducted by Öyedele *et al*., (2002), the repellent effect of lemongrass oil against *Aedes aegypti* was tested. As a result of the study, it was observed that 20% and 25% concentrations of lemongrass oil

against *Aedes aegypti* showed a repellent effect for one hour. It was determined that the repellent effect decreased to 94% after 3 hours and to 44% after 5 hours. It has been determined that lemongrass oil has a 100% repellent effect against *Musca domestica*. In a study by Jovanovic (history), it was seen that the repellent effect of lemongrass oil against *Musca domestica* was effective for 1 hour at a concentration of RC95 = 0.010 µL/cm3. However, as a result of microencapsulation of lemongrass oil with pectin and gelatin, it was determined that the protection effectiveness was extended up to 7 days.

3.9 Lemon Eucalyptus Oil (*Corymbia citriodora*)

Lemon eucalyptus oil (*Corymbia citriodora*) is known as an effective repellant due to its citronellal content of approximately 85%. Due to the high volatile effect of the citronellal content, it is effective for up to 1 hour. A study by Kiplang and Mwangi (2014) found that at 1% concentrations, essential oil of lemon eucalyptus was more effective against *Aedes aegypti* (97.37%) than neem oil (55.26%). Laboratory studies have shown that eucalyptus oil is as effective as 20% of the chemical DEET against *Anopheles mosquito* species (Fradin, 2019) [23].

According to Maguranyi *et al*., (2009) [37] it was revealed that the repellent effect of eucalyptus essential oils against *Aedes aegypti* does not last very long, but provides protection for only 10 to 25 minutes. It has been proven by a study that lemon eucalyptus oil has a 100% repellent effect against *Culex quinquefasciatus* for 100 minutes. In another study, the repellent effects of microencapsulated thyme and lemon eucalyptus oils against *Aedes aegypti* were investigated. At the end of the research, it was determined that the repellent effect of lemon eucalyptus oil against *Aedes aegypti* was higher than that of thyme oil and showed a 100% repellent effect for 10 days (Maia, 2019). In studies on Lemon Eucalyptus oil, it has been found that it has a high repellent effect against *Ixodes ricinus, Aedes albopictus, Mansonia and P. humanus capitis* (Jaenson *et al*., 2006; Yang and Ma, 2005; Hadis *et al*., 2003; Toloza. *et al*., 2008) [26, 61, 21, 60]. In another study, a repellent effect of Lemon Eucalyptus oils against *Leptoconops* was determined (Carroll and Loye, 2006) [15]. In another study, it was determined that *H. suaveolens* (L.) *Poiteau* has an insecticidal effect against pest of stored product and a repellent effect against the adults of the Asian tiger mosquito (Conti *et al*. 2011) [11].

3.10. Clove Oil (*Syzygium aromaticum*)

Clove (*Syzygium aromaticum*) is an aromatic plant belonging to the *Myrtaceae* family, containing eucalyptus. Eugenol (≤82%), the remaining components are; eugenol acetate, β-caryophyllene and α-humulene (De Groot, 2016) [19]. Clove essential oil increases the permeability activity of the cell membrane; disrupting the cytoplasmic membrane and proteins; it inhibits ATPase, histidine decarboxylase, amylase and protease enzymes (Haro-Gonzalez, 2021). As a result of the studies, it was determined that clove oil had the highest egg laying inhibitory and lethal effect, LC_{50} values were 1.20-10.55, and had a 100% repellent effect. It has been observed that clove oil has a higher toxic effect than cypermethrin and lemongrass.

3.11. Citronella Oil (C*ymbopogon nardus*)

Cymbopogon nardus (L.); it is an essential oil-producing perennial aromatic grass of the *Poaceae* family that grows in tropical and subtropical regions including Asia, Africa and America. Essential oils obtained from *C. nardus* are known as citronella oil; It has three main active ingredients: citronellal, citronellol and geraniol (Wany *et al*. 2014). It has also been determined that citronella oil has a repellent effect (Nerio *et al*. 2010; Ranasinghe *et al*. 2016; Shivhare *et al*. 2018; Yadav *et al*. 2014) [38]. However, due to the harmful effects of synthetic compounds on humans and the environment, the use of only natural compounds is becoming a more preferred method of control.

Citronella Grass Oil is one of these natural components. Citronella Grass Oil was first registered by the US Environmental Agency. Citronella Grass Oil is one of the most studied compounds in the field of natural insect repellents and has a wide range of bioactivity depending on the target organism (Fradin, 2019) [23]. The mosquito repellent activity of Citronella Grass Oil lasts up to 2 hours, similar to DEET. Citronella Grass Oil has a toxic effect when the repellent activity against tick larvae seen in tropical horses exceeds 12.5%. The active compounds of citronella oil are camphor, eucalyptol, eugenol, linalool, citronellal and citral (Tangpoa, 2022). Citronella is particularly effective on mosquitoes (Zhang, 2020) [59]. Citronella oil is extracted by cutting into small pieces. It has antiseptic and bactericidal properties (Echodu, 2020) [24]. Citronella oil has no risk to human health. The mechanism of the insecticidal citronella oil blocks the nervous system of insects, disrupts the metabolism and prevents the insects from feeding. Concentrations of citronella essential oil, as low as 400 mg/L also exhibit antifungal properties against Aspergillus, which causes black mold on fruits. However, 2.5 µl/ml and higher concentrations of Citronella essential oil are toxic to fruits and vegetables. Contains citronella essential oil, citronellal, citronellol, nerol and elemol.

These compounds contribute 1200–20,000 µg/mL to the antimicrobial properties of citronella oil (Kaur, 2021) [28]. In a study, microencapsulation of Citronella oil with β-cyclodextrin increased the repellent effectiveness of *Aedes aegypti* on cotton fabric for more than 30 days (Phasomkusolsil, 2010) [43]. In another study by Phasomkusolsil and Soonwera, citronella herb oil; it has been proven to have both a repellent and a deterrent effect against species such as *Aedes aegypti*, *Anopheles minimus* and *Culex quinquefasciatus* (Phasomkusolsil, 2010) [43]. Studies have shown that citronella oil provides full protection against insects, but this protection lasts for 2 hours. This decrease in efficacy is thought to be due to the rapid evaporation of the citronella oil. Improvements have been made using encapsulation techniques to reduce this evaporation rate. In a study conducted; the repellent effect of different concentrations and formulated lotions (0, 2, 3, 4, 5% w/w) of citronella oil against *Aedes aegypti* was investigated. The data obtained as a result of the study; It has been proven that the repellent activity of lotions containing citronella oil is dependent on the concentration of the lotions. It was determined that 5% concentration of citronella oil showed the highest repellent effect (Phasomkusolsil, 2010) [43].

3.12. Marigold (*Tagetes minuta*)

A Brazilian study evaluated the insecticidal activity of *Tagetes minuta* (*Asteraceae*) marigold against head lice. For this purpose, lice taken from the heads of children aged 6-12 were placed in petri dishes on which filter papers impregnated with 100 ppm essential oil were placed. Then, 0.1 ml of T. minuta extract was dripped onto the lice. Petri dishes were

placed in a dark environment (growth room) (30 ºC and 70% relative humidity). As a result of the research, it was observed that Tagetes minuta (*Asteraceae*) had an insecticidal effect on lice (Tereschuk *et al*. 2003) [56].

Studies have shown that extracts of *Tagetes minuta (Asteraceae)* are also effective in many infections besides head lice (fungus) virus and gram positive and negative bacteria (Tereschuk *et al*. 2003) [56]. Another study by Perich *et al*., (1995) [42] and insecticidal activity against mosquitoes (Keita *et al*. 2000) [57].

Conclusion

In the light of the researches, it has been seen that essential oils, which are used as an alternative to chemical applications and are friendly to human health and the environment, are used effectively in the fight against pests. In a study on the intercropping farming system, pest population density was investigated among apple orchards with *Mentha canadensis* L., *Ageratum houstonianum* Mill. *Tagetes patula* L. and *Ocimum basilicum* L. species.

In this study, when planting with natural vegetation and aromatic plants is compared, it was observed that the pest population decreased significantly in the orchard planted with aromatic plants, but the pest population increased only during the flowering period of aromatic plants. Brown and Schmitt (2001) [10] in their study; Peach trees planted together with apple orchards showed that it was effective in attracting both pest species and parasitoids.

On the other hand, Carlsen and Fomsgaard (2008) [14] made intercropping agriculture with peach orchards and white clover. As a result of the research, it was seen that peach orchards increased the pest population and the number of natural enemies. When the intercropping agriculture system is examined; several hypotheses have been identified. The first of these; repellent effect or attractant effect due to the odors emitted by intercropping products; it is the increase in the pest population due to the increase in the food source of the pests with the cultivated intercroping product (Uvah and Coaker 1984).

In another research conducted; in corn and Sorghum fields; intercropping species such as molasses (*Melinis minutiflora*), silver leaf (*Desmodium uncinatum*) and green leaf (*Desmodium intortum*) have been shown to have a repellent effect for rootworm species (Khan *et al*. 2000).

This review, which investigates the possibilities of using plant essential oils (EO), which is among the biologically active components, in the fight against pests will shed light on future studies on this subject.

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