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Insects pest repellent, essential oils, is can be an efficacious alternative to synthetic pesticides

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Abstract
The aim of this study was to verify the degree of repellent effect of two chemical substances (DEET and 2-undecanone) and three essential oils (EOs), *Allium sativum, Lavandula angustifolia* and *Eucalyptus globulus*. *Leptinotarsa decemlineata* Say. Were exposed to different concentrations (0.2, 0.4 and 0.6%) in a two-choice olfactometer and (0.02, 0.04 and 0.06 ml/cm^2) area preference assay. The effect was recorded 15 minutes, in olfactometer and 6-24 hours in area preference test, after the application of the treatments. It was found that *A. sativum, E. globulus,* and *L. angustifolia* had a significant repellent effect. We also found that the repellent effect increased with increasing concentration and time. An olfactometer and area preference assay achieved the highest repellency index (%) from (A. *sativum, E. globulus, L. angustifolia*, deet, and 2-undecanone), indicating RI 80% (15mins) and RI 93% at 6-24 hours in concentration (0.6%, 0.06 ml/cm^2). The present results show that the tested oils have high activity against *L. decemlineata*. We concluded that the EOs may have potential as an alternative to chemical control, all these efficient EOs could be used as effective biocontrol agents against various field pests.

Keywords: Repellent, olfactometer, essential oils, synthetic pesticides, *L. decemlineata*

Introduction

The Colorado potato beetle (*Leptinotarsa decemlineata* Say) is the most important pest of potato (FAO STAT, 2020) [9]. It is widespread in North America, Europe, and Asia, covering about 16 million km2, and continues to spread (James, 2011) [20]. In the 20th century, this pest became a major problem throughout Europe, Asia, and China (Oerke, 2006) [27]. Defoliation can reduce tuber yield by, more than 50% (James, 2011) [20]. The first recorded case of plant protection by chemical insecticide was found in the 1950s after the application of DDT (James 2011) [20]. Over time, CPB developed resistance to many insecticides which were initially effective (FAO STAT, 2020) [9]. Up to day, more than 300 cases of *L. decemlineata* resistance to 56 insecticidal agents have been detected (FAO STAT, 2020) [9]. In addition, different alternative chemical control methods have been introduced since the 19th century that have minimized CPB infestations. Crop rotation, trap crops, and other agrotechnical practices have been recommended to farmers (Hin, 2009) [14]. It has been concluded that the only two reliable methods are hand picking and mating with green. Hand picking, especially before mating, was found to be very effective but impractical on a larger scale. Therefore, most alternative methods for CPB management have failed, and it's high time to look for more economical and sustainable means (Isman, 2006) [15].

EOs can contain many terpenes and low molecular weight phenolic substances and are easily extracted from plant material by steam distillation (Regnault-Roger, 2008) [31]. Studies in several countries have confirmed that some plant essential oils repel insect pests and used insecticidal activity on certain pests upon contact or by fumigation (Regnault-Roger, 2008 & Mukarram *et al*., 2021a) [31, 26]. Several commercial bioinsecticides are based on plant extracts (essential oils) or their chemical compositions in many major agricultural regions, including: Europe, USA, China, and Latin America (Isman, 2017) [16]. The study literature reports that the plant species with insect repellent activities and their active ingredients have been published by (Isman & Machal 2006; Khallaayoune *et al*., 2009; González-Coloma *et al*., 2010 & Regnault-Roger 2013)[18, 22, 12, 32], includes Aartemisia *vulgaris* L. (Thujone, cineole), *Cinnamomum camphora* (L.) Presl (cinnamaldehyde), *Curcuma longa* L. (turmerone), *Eucalyptus globulus* Labill, *Myrtus communis* L. and *Rosmarinus officinalis* L. (cineoles), *Juniperus virginiana* L. (α and β pinene, methyl-eugenol), *Lavandula angustifolia* Mill, (linalool, lynalyl acetate), *Litsea cubeta* Pers., and *Cymbopogon* species (*citral, citronellal,* citronellol), *Melaleuca leucaden-dron* L. (terpineol, γ-terpinene), *Mentha pulegium* L. (pulegone), *Mentha piperita* L. (menthone, menthol), *Nepeta cataria* L. (nepetalactone), *Pelargo-nium* sp. (Geraniol), *Syzygium aromaticum* L. (eugenol), *Thymus* sp. And *Origanum vulgare* L. (thymol, carvacrol, p-cymene).

In a laboratory investigation, the essential oils of *Allium sativum* Linnaeus, 1793 showed insecticidal activities on different Coleoptera pests (Abdalla *et al*., 2017) [1]. Garlic extract had effective repellent activity against *Tribolium castaneum* (Herbst, 1797) (Jahromi *et al*., 2012) [19]. The major chemical compositions of *eucalyptus* oils are 1, 8-cineole and α-pinene or 1, 8-cineole and linalool (Boukhatem *et al*., 2020) [3]. The essential oil of *Allium sativum* Linnaeus, 1793, comprise sulphur-containing organic molecules, mainly diallyl disulfide, allyl propyl disulfide, allyl sulfoxide, and allicin. The activity of diallyl disulfide as a fumigant against many insects and pathogens was qualified by Chiam *et al*., (1999) [5]. Various essential oils are used in registered commercial biopesticides, especially in developed countries. Among these products, garlic oil is the most commonly used (Regnault *et al*., 2012) [30]. The most effective and well-known insect repellents currently on the market are DEET (N, N-diethyl-3-methylbenzamide) and 2-undecanone (Maia, & Moore, 2011) [24]. DEET, an active ingredient used worldwide since 1946, is a highly effective repellent for a variety of insect species (Maia, & Moore, 2011) [24]. 2-undecanone (methyl nonyl ketone), a natural non-toxic insect repellent compound, has been found in palm kernel oil and soybean oil (Sanghong *et al*., 2015) [33].

Considering the needs for sustainable and environmentally friendly pesticides and the efficacy of EOs. The aim of our study was to investigate the repellency of *A. sativum*, *L. angustifolia* and *E. globulus* EO as plant secondary metabolites against Colorado potato beetle under laboratory conditions.

Materials and Methods

Basic experiment information

This study was carried out at the Laboratory of Entomology, Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra. Laboratory investigations were divided into two experiments. The experiment included "two-choice olfactometer" repellency and Area preference assay with eight EOs, two chemicals against the *L. decemlineata*. The study was carried out under the laboratory conditions at the temperature of 20 ± 1 °C, humidity 50 ± 1%, and /light/dark 16:08/ h.

Insects used: Adults of the L. *decemlineata* were collected from a potato culture at a local field in Nitra (Slovakia) 48°18'16.7"N 18°05'41.3"E in August-September 2021. Nutrients were potato tubers as adult foods. Approximately 1000 adults were incubated at 20 ± 1 °C and 50% relative humidity (RH) under a long day (16/8 h) photoperiod in plastic boxes (74 cm x 52 cm x 28 cm). Adults of both sexes of the approximately same age were used in the experiments.

Essential oils and chemical substances used

Essential oils were from plant species *A. sativum*, *L. angustifolia* and *E. globulus*. The most important chemicals in *A. sativum* EO were diallyl disulphide, diallyl trisulphide, and diallyl sulphide, in the case of *L. angustifolia* they were citral, coumarin, eugenol, geraniol, limonene, linalool, in EO from *E. globulus* they were 1,8 cineole, dipentene, alpha phellandrene, beta pinene. Commercial chemical substances were purchased from Sigma-Aldrich (DEET (N, N-diethyl-3-methylbenzamide) at concentration 97%. 2-Undecanone (methyl nonyl ketone) in concentration 99%. According to the website of this company and Fusková, & Cagáň, (2021) [10].

(https://www.mysticmomentsuk.com/collections/essential-oils?grid_list=grid-view).

Table 1: Dosage used in laboratory experiment

EOs/Dose (µl)	Dose (ml)	Solvent (acetone)/ ml	Concentration%
20	0.02	10	0.2
40	0.04	10	0.4
60	0.06	10	0.6

V/V% = [(Volume of solute)/ (Volume of solution)] x 100%

Application of essential oils in two-choice olfactometer test

The experiments were conducted using a Y-tube-olfactometer. A 0.2%, 0.4% and 0.6% tested essential oils of each solution was dosed on a piece of filter paper (No. 2, 10×20mm), odour sources were placed in the treatment arm, and a filter paper treated with 10 µl of acetone was placed in the control side. Five replicates were used for each concentration%. Each replicate consisted of 5 responding CPB adults were leased individually into the olfactometer using flexible forceps. The measurement started after 15 minutes. The choices of the CPB were recorded. The calculated repellency index was % RI = (1 − (%T ⁄%C)) × 100, where % T is the percentage of insects on the treated arm and% C is the percentage of individuals on the control arm.

Area preference assay

The repulsive effect was determined by the area preference method on filter paper as described by (Abdel-Tawab, 2016) [2]. Filter paper (Whatman N°1) with a diameter of 9 cm was cut into two halves, and 10 µl of each concentration (0.02, 0.04, and 0.06 ml/cm^2) of treated Eos was applied separately to one half of the filter paper using a pipette. The second half (control) was treated with 10 µl of the solvent (acetone).

Both halves of filter paper were allowed to dry at room temperature for 10 minutes. The test insects (five adults) were released in the center of each filter paper and the Petri dish was immediately covered. Each treatment was repeated three times. The average duration of a repetition was 6 and 24 hours. The coverings of the Petri dishes were ventilated through tiny-holes whose diameter was tiny-enough to prevent insects from escaping. Petri dishes were labeled to prevent mixing of treated and untreated sides. The repellency percent (PR%) of the treatment oils was calculated using the following formula: The calculated repellency index was % RI = (1 - (%T /%C)) × 100, where%T is the percentage of insects on the treated arm and % C is the percentage of individuals on the control arm.

Table 2: The scheme of the experiment №.

Factor A: Concentration,% and ml/cm^2		Factor B: Time after treatment				Factor C – EOs for treatments	
1.	0.2	Olfactometer		Area preference		1.	*E. globulus*
2.	0.4	Minutes		Hours		2.	*L. angustifolia*
3.	0.6	1.	15	1.	6	3.	*A. sativum*
//	//	//	//	2.	24	4.	*Deet*
//	//	//	//	//	//	5.	*2-Undecanone*

Table 3: Chemical constituents (%) of *A. sativum*, *E. globulus*, and *L. angustifolia* essential oils included in repellency bioassays.

Compounds	Relative amount%		
	A. sativum	***E. globulus***	***L. angustifolia***
Limonene	-	≤28.75	≤0.74
Linalool	-	≤1.66	≤35.75
Citral	-	≤28.53	≤0.04
Eugenol	-	≤0.14	≤0.00
Methyl allyl sulfide	≤2.39	-	-
Dimethyl disulfide	≤0.543	-	-
Diallyl sulfide	≤5.283	-	-
Methyl allyl disulfide	≤11.293	-	-
Dimethyl trisulfide	≤0.628	-	-
Diallyl disulfide	≤37.231	-	-
Methyl allyl trisulfide	≤8.338	-	-
Diallyl trisulfide	≤18.287	-	-
Diallyl tetrasulfide	≤3.819	-	-
Geraniol	-	≤6.43	≤0.66
Citronellol	-	≤0.67	≤0.00

According to Fusková, & Cagáň, (2021) [10] and the web page of this company (https://www.mysticmomentsuk.com/collections/essential-oils?grid_list=grid-view)

Results

Two-choice olfactometer test: All of the investigated plant essential oils *A. sativum*, *E. globulus*, *L. angustifolia* essential oil and two Deet and 2-Undecanone against *L. decemlineata* at all higher of the tested concentrations 0.6% caused a repellency index% higher a 80% (Table 5). On all 15 minutes of the investigation, the highest RI% rate of the *L. angustifolia* adults was observed at the highest concentration 0.6% with an *A. sativum, L. angustifolia* and 2-Undecanone.On the other hand, the lowest concentration 0.2% was observed the lowest repellency index 20% at all treated substances. The average repellency activity were increases with increasing the concentration and time 0.2% (0.7), 0.4% (0.5) and 0.6% (0.3) (Table 4). The average repellency activity was observed at the all concentrations and times, it was as follows: A "2-Undecanone (0.2), *A. sativum* (0.3), *L. angustifolia* (0.3), Deet (0.3) and *E. globulus* (0.4)" (Table 4).

Table 4: The average amount of *L. decemlineata* through experiment depending on the 1) concentrations%, (2), time per minutes (3), treated EOs and chemicals after application and (4) overall average number of insects in treated side.

(1) Concentration %	(4) Average number of insects/concentration	(2) Time after treatment, min	(4) Average number of insects/min	(3) EOs and chemicals	(4) Average number of insects/ EOs and chemicals
0.2	0.7				
0.4	0.5	15	1.5	*A. sativum*	0.3
0.6	0.3	//	//	*E. globulus*	0.4
//	//	//	//	*L. angustifolia*	0.3
//	//	//	//	DEET	0.3
//	//	//	//	2-Undecanone	0.2

Concentrations %, (2), time per minutes (3), treated EOs and chemicals after application and (4) overall average number of insects in treated side.

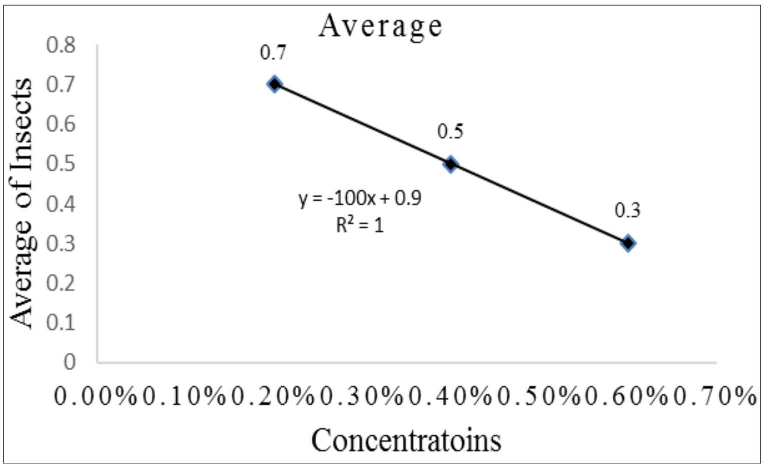

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Fig 1: The correlation field between average amount of *L. decemlineata* (X) and concentration levels of all EOs (Y).

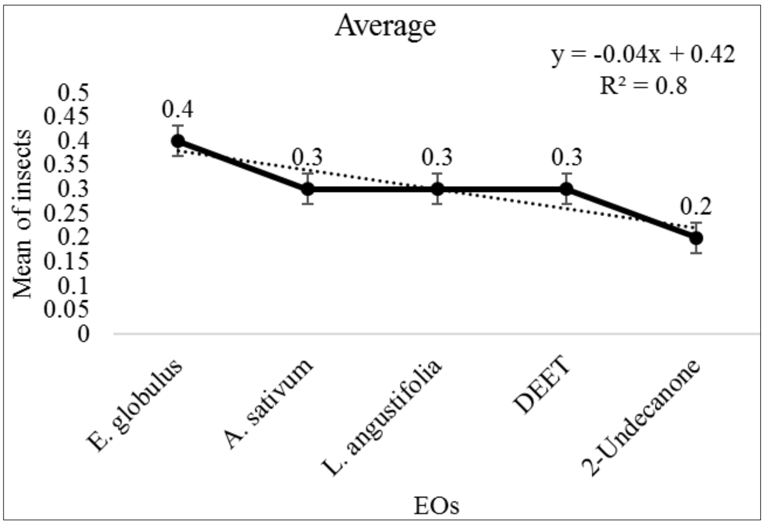

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Fig 2: The correlation field between average amount of *L. decemlineata* (X) and overall treated EOs (Y).

Table 5: The average repellency effect of the chemicals and EOs to the adults of Colorado potato beetle, *Leptinotarsa decemlineata*. The repellency was based on two-choice olfactometer test. Five adults were included to each two-choice olfactometer test. Five replications were done for each concentrations (0.02, 0.04 and 0.06%). For each replication duration was 15 minutes. Standard deviation SD ±, Data variation,% and the calculated repellency index was % RI = (1 − (%T ⁄%C)) × 100, where % T is the percentage of insects on the treated arm and % C is the percentage of individuals on the control arm.

Concentration,%	Time after, min	Variation indexes		Data variation,%	Control	RI,%
		Average	Standard deviation, SD			
A. sativum						
0.2	15	0.8	0.5	1.3	1	20
0.4	15	0.4	0.5	2.5	3	60
0.6	15	0.2	0.4	4.3	4	80
E. globulus						
0.2	15	0.8	0.7	1.8	1	20
0.4	15	0.8	1.0	2.5	1	20
0.6	15	0.6	0.4	1.5	2	40
L. angustifolia						
0.2	15	0.8	0.1	0.2	1	20
0.4	15	0.4	0.5	2.5	3	60
0.6	15	0.2	0.4	4.3	4	80
DEET						
0.2	15	0.6	0.8	2.8	2	40
0.4	15	0.4	0.2	0.9	3	60
0.6	15	0.4	0.5	2.5	3	60
2-Undecanone						
0.2	15	0.6	0.8	2.8	2	40
0.4	15	0.4	0.9	4.3	3	60
0.6	15	0.2	0.4	4.3	4	80

Results of Repellency activity of an area preference assay

The results of repellent activity of *A. sativum*, *E. globulus*, *L. angustifolia* (EOs) and two chemical substances deet and 2-undecanone against *L. decemlineata* are summarized in (Table 7 and 8), respectively. All essential oil and the chemicals showed significant repellent activity (RI%) at the concentrations used. An average number of repellency effects was observed between treated and untreated half filter paper disk for the oil formulation (0.2, 0.4, and 0.6 ml/cm2). The repellency index (RI%) was range 73 to 93% after 6 hours and 80 to 93% after 24 hours for all EOs (*A. sativum*, *E. globulus*, *L. angustifolia*, deet and 2-undecanone) and concentrations (0.2, 0.4 and 0.6 ml/cm2). (table 6) shows the average number of insects on the treated side, all essential oils showed mode rate repellency activity lower with an average repellency values of 2.8 at 0.02 µl/cm2. The repellency was strongest in the first 24 hours after treatment. This pattern was observed in Table 7 and 8, which show that Eos achieved the highest repellency index (%) using CPB from (A. *sativum*, *E. globulus*, *L. angustifolia*, deet, and 2-undecanone), indicating 93% repellency at 6 and 24 hours in concentration (0.06 ml/cm2). The average repellency activity increased with increasing concentration and time 0.2 (2.8), 0.4 (1.9) and 0.6 ml/cm2 (1.7), (table 6). The average repellency activity was observed at all concentrations and times, and was as follows: A "2-undecanon (0.5), *A. sativum* (0.5), *L. angustifolia* (0.6), *E. globulus* (0.9), and Deet (1.0)" (table 6).

Table 6: The average amount of *L. decemlineata* through experiment depending on the (1) concentrations ml/cm^2, (2), time per hours (3), treated EOs and chemicals after application and (4) overall average number of insects in treated side.

(1) Concentration ml/cm2	(4) Average number of insects	(2) Time, hours	Average number of insects per (concentrations and hours)	(4) Average number of insects total time	(3) Eos and chemicals	(4) Average number of insects
0.2	2.8					
0.4	1.9	6	1.6	3.7	*A. sativum*	0.5
0.6	1.7		1.1 1.0		*E. globulus*	0.9
//	//		1.2		*L. angustifolia*	0.6
//	//	24	0.8	2.7	DEET	1.0
//	//		0.7		2-Undecanone	0.5

Concentrations ml/cm^2, (2), time per hours (3), treated EOs and chemicals after application and (4) overall average number of insects in treated side.

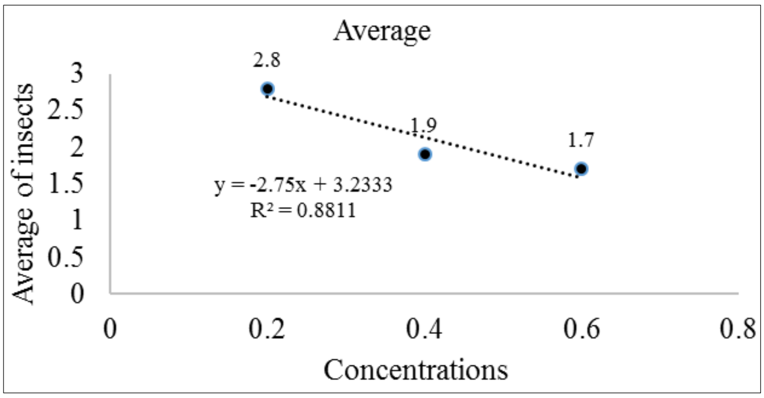

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Fig 3: The correlation field between average amount of *L. decemlineata* (X) and concentration levels of all EOs (Y).

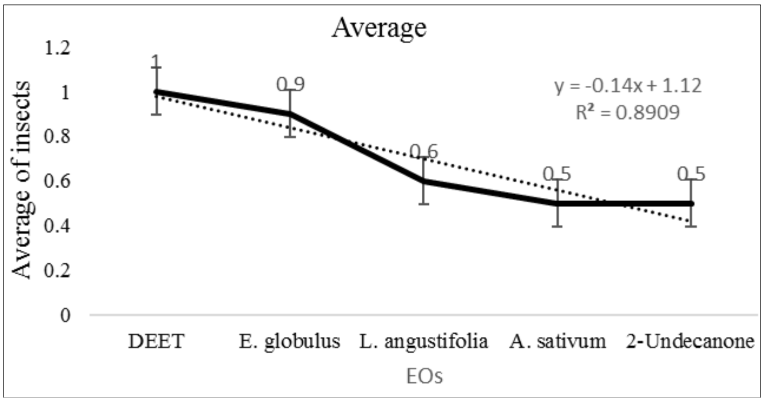

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Fig 4: The correlation field between average amount of *L. decemlineata* (X) and overall treated EOs (Y).

Table 7: The average repellent efficacy of the chemicals and of Eos against adults *L. decemlineata* after 6 hours. Repellent efficacy was based on area preference test. Three replicates were used for each concentration (0.02, 0.04, and 0.06 ml/cm^2). Standard deviation SD ±, data

variation,%, and Repellency index was calculated as%RI = ((1 - (% T /% C)) × 100, where%T is the percentage of beetles on the treated filter paper half-disk and%C is the percentage of individuals on the control filter paper half-disk in the Petri dish. Five adults were placed in each Petri dish.

Repellent	Concentrations/ ml/cm^2	Average number of adults counted after 6 hours				
		Average	SD	Control	Data variation,%	RI,%
A. sativum	0.2	0.7	0.6	4.3	8.7	87
	0.4	0.3	0.6	4.7	17.3	93
	0.6	0.3	0.6	4.7	17.3	93
E. globulus	0.2	1.3	0.6	3.7	4.3	73
	0.4	0.3	0.6	4.7	17.3	93
	0.6	1.3	2.3	3.7	17.3	73
L. angustifolia	0.2	0.7	1.2	4.3	17.3	87
	0.4	0.7	1.2	4.3	17.3	87
	0.6	0.7	1.2	4.3	17.3	87
DEET	0.2	1.3	1.2	3.7	8.7	73
	0.4	1.0	1.0	4.0	10.0	80
	0.6	0.7	1.2	4.3	17.3	87
2-Undecanone	0.2	0.3	0.6	4.7	17.3	93
	0.4	0.7	0.6	4.3	8.7	87
	0.6	0.3	0.6	4.7	17.3	93

Table 8: The average repellency effect of the chemicals and Eos against adults of *L. decemlineata* after 6 hours. The repellency was based on area preference assay. Three replications were used for each concentrations (0.02, 0.04 and 0.06 ml/cm^2). Standard deviation SD ±, Data variation,% and The repellency index was calculated as % RI = ((1 – (%T ⁄%C)) × 100 where % T is the percentage of beetles on the treated half-disk of filter paper and % C is the percentage of individuals on the control half-disk of filter paper in the Petri dish. Five adults were included in each Petri dish.

Repellent	Concentrations/ ml/cm^2	Average number of adults counted after 24 hours				
		Average	SD	Control	Data variation,%	RI,%
A. sativum	0.2	0.3	0.6	4.7	17.3	93
	0.4	0.3	0.6	4.7	17.3	93
	0.6	0.3	0.6	4.7	17.3	93
E. globulus	0.2	1.0	1.0	4.0	10.0	80
	0.4	0.3	0.6	4.7	17.3	93
	0.6	0.3	0.6	4.7	17.3	93
L. angustifolia	0.2	0.3	0.6	4.7	17.3	93
	0.4	0.3	0.6	4.7	17.3	93
	0.6	0.3	0.6	4.7	17.3	93
DEET	0.2	1.0	1.0	4.0	10.0	80
	0.4	0.7	0.6	4.3	8.7	87
	0.6	0.3	0.6	4.7	17.3	93
2-Undecanone	0.2	0.7	0.6	4.3	8.7	87
	0.4	0.3	0.6	4.7	17.3	93
	0.6	0.3	0.6	4.7	17.3	93

Discussion

Insect repellents are substances that extracted locally to keep insects from flying onto, settling on, or stinging the skin of human or animals. Certain volatile plant compounds and essential oils derived from plants are known to repel various pest species and are considered minimal risk pesticides. The repellency of the essential oils and the two chemicals against adults *L. decemlineata* is shown in Tables 5, 7, and 8, where the repellency generally increased with increasing concentration. On the other hand, the lowest repellency was observed at the lowest concentrations for all concentrations tested. The highest repellency (93%) of the oils were found at the highest concentrations with the area preference-based test, and the highest repellency rate (80%) of the two-choice odour test was also found at the same highest concentrations. Some study was found the fruits of *Melia azedarach* showed excellent repellency against many insects as reported by Panji, (1964) [28], who found that a 5% ethanolic extract of *Melia azedarach* repelled adults *Aulacophora foveicollis* L. Kebede *et al*., (2010) [21], found that a 5% ethanolic extract of *Melia azedarach* repelled at least 30% of *Raphidopalpa foveicollis* Lucas beetles (1 hour) and a maximum of 65% of beetles (48 hours), while a 10% extract repelled a maximum of 76% of beetles in 48 hours. *Melia azedarach* oil at 2% concentration provided 95.13%, for 7 hours and 20 minutes, while the 5% oil provided 96.20%, for 8 hours and 20 minutes against *Phlebotomus orientalis* (vector of visceral leishmaniasis), (Kebede *et al*., 2010) [21]. Our study showed the potential of DEET and 2-undecanone and especially *A. sativum*, *E. globulus*, *L. angustifolia* essential oil against *L. decemlineata*. In last years, the number of research publications on the use of plant biopesticides as pest control agents in integrated pest management has increased exponentially. In addition, many laboratories worldwide have concentrated studies on essential oils and their constituents to exploit their biopesticides properties (Grumezescu, 2017) [13]. However, despite these advances, there are still few commercially available products based on essential plant oils or their isolated components (Dougoud el al., 2019) [8]. Recently, the use of repellents has attracted the interest of scientists and the crop protection industry (Isman, 2000) [17]. The most promising are DEET and 2-undecanone, which are already used as ingredients in insect repellents (Witting-Bissinger *et al*., 2008) [36].

Extracts of *Allium sativum* have considerable acaricidal and insecticidal properties against Coleoptera and Diptera pests (Abdalla *et al*., 2017) [1]. As well as the results in (Plata-Rueda *et al*., 2017 & Moncada *et al*., 2021) [29,25]. As reported by Fusková, & Cagáň, (2021) [10], who found that the high repellency (90%) against *Tenebrio molitor* and high affinity to *A. obtectus* and *T. confusum*. Strikingly, high efficacy (95%) was observed even at the lowest concentration (0.01%). Our results confirmed high repellency (93% within 6 and 24 hours) against *L. decemlineata,* with the highest concentration (0.06%) based on an area preference test and a two-choice odour test.

The use of *Eucalyptus* EO in our study showed the results of high repellency (93% within 24 hours), with the odor test based on area preference test and two choice, was found in the highest concentration (0.06%). Simillar results were also obtained by (Shahriari *et al*. 2019) [34]. *Eucalyptus globulus* EO had a significant effect on *T. confusum* and *A. obtectus*, which was simillar to the repellency previously determined for *E. Kuehniella* (80% within 24 hours).

L. angustifolia EO confirmed in our results a high repellency (93% within 6 and 24 hours) against *L. decemlineata*, with the highest concentration (0.06%) based on an area preference test and a two-choice odor test. According to the research of Germinara *et al*., (2017) [11], the repellent activity of *L. angustifolia* EO seems to be high against all the pests tested (80%). The effect was detectable even at low concentrations, which is consistent with the results obtained for *S. granaries*. Moreover, the repellent effect was also significant, as also confirmed in various studies with different EOs (Chaudhari *et al*., 2021; Tu *et al*., 2017& Conboy *et al*., 2020) [4,35,6]. Thus, we can conclude that these EOs may have significant potential against a wide range of pests.

In summary, chemicals pesticides and repellency their kill rapidly target pests and provide highly control when applied. However, their application leaves toxic residues in field crops, soil, and stored grains that are harmful to consumers. Therefore, a new and valuable alternative approach should be found to reduce the use of insecticides in field warehouses and stored grains. One possible method is the encapsulation and emulsification of plant EOs as surfactants in greenhouses (De Oliveira *et al*., 2019) [7]. The second is the direct application of EOs. Both approaches could be powerful tools for integrated management of field and storage pests. However, more research needs to be done in the laboratory and in the field.

Conclusions

Novel insect pests repellency of the essential oils in our study was not established on particularly chemicals compositions to essential oils. The tested plant essential oils had the negative impact on L. decemlineata. Our results show that an Eos of *A. sativum*, *E. globulus*, and *L. angustifolia*, and the two chemicals deet and 2-undecanone were most effective against L. decemlineata. We also found that the most effective essential oils still showed elegant repellent effect when mingled to small concentrations. These essential oils can be suggested as adequate biopesticides agents under different controlled environmental conditions.

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