LARVICIDAL, ADULTICIDAL AND GROWTH INHIBITORY EFFECTS OF MONOTERPENES ON *CULEX PIPIENS* L. (DIPTERA: CULICIDAE)

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ABSTRACT

Twelve monoterpenes were evaluated for their larvicidal and adulticidal toxicity against *Culex pipiens*. Geraniol and cuminaldehyde were significantly the most toxic monoterpenes to mosquito larvae with LC_{50} values of 38.56 and 38.94 mg/l after 24 hr of treatment, respectively, whereas cuminaldehyde was the most potent compound after 48 hr of treatment, followed by geraniol and thymol. In the fumigant toxicity experiments, (−)-carvone and geraniol were the most toxic monoterpenes against the adults at the three tested concentrations and after both tested exposure times. Sublethal concentration (0.5 LC_{50}) of (−)-carvone, (−)-limonene and cuminaldehyde caused remarkable decreasing in hatchability, pupation and adult emergence as well as induced high larval mortality. The results obtained suggest that geraniol, cuminaldehyde and (−)-carvone are promising as toxicants against *Culex pipiens* and could be useful in the search for new natural insecticides.

Key words: Monoterpenes, insecticidal activity, growth inhibitory, *Culex pipiens*

INTRODUCTION

Mosquitoes are responsible for spreading serious human diseases such as malaria, dengue, filariasis, Japanese encephalitis and yellow fever (Paul *et al*., 2006). They transmit diseases to more than 700 million people annually (Taubes, 2000). Malaria is one of the most devastating diseases affecting humans, with approximately 2.5 million annual deaths (Lowenberger *et al*., 1999). *Culex pipiens* L. (Diptera: Culicidae) is an important vector of several human pathogens, such as West Nile virus, Rift Valley Fever virus, and *Bancroftian flariasis* (Meegan *et al*., 1980; Claire and Callaghan, 1999). This insect has a wide distribution throughout the tropical and subtropical areas. In Egypt, *C. pipiens* is the most common mosquito species in urban and rural areas, causing a health risk and nuisance to human.

The control of mosquitoes worldwide depends primarily on continued applications of organophosphates such as temephos and fenthion, insect growth regulators such as diflubenzuron and methoprene, and bacterial larvicides such as *Bacillus thuringiensis* and *Bacillus sphaericus* (Rozendall 1997; Chavasse and Yap 1997). Although effective, their continuous use has disrupted natural biological control systems and resulting in the widespread development of resistance. These problems have warranted the need for developing alternative strategies using ecofriendly products for mosquito control. Plants offer an alternative source of insect control agents. They contain a wide range of bioactive chemicals, many of which are selective and have little or no harmful effect on non-target organisms and the environment. In this context, essential oils and their major constituents, monoterpenes, have received much attention as potentially useful bioactive compounds against insects.

Monoterpenes are the main constituents in the majority of plant essential oils. These compounds give plants their unique odoriferous properties because of their lower boiling points. Monoterpenes can be classified into two major groups: monoterpene hydrocarbons and oxygenated monoterpenes. The later group includes alcohols, aldehydes, ketones, ethers and acids (Templeton, 1969). The natural pesticidal properties of some monoterpenes make them useful as potential alternative pest control agents as well as good lead compounds for the development of safe, effective, and fully biodegradable pesticides. Monoterpenes had been shown to possess remarkable pesticidal activities, including insecticidal (Isman, 2000; Grodnitaky and Coats, 2002), herbicidal (Duke *et al.*, 2000; Singh *et al.*, 2002), fungicidal (Wuryatmo *et al.*, 2003; Cärdenas-ortega, 2005), bactericidal (Cristani *et al.*, 2007; Cantore *et al.*, 2009) properties.

In fact, many studies have been conducted on the insecticidal properties of essential oils against various mosquitoes (Shalaby *et al.*, 1998; Cheng et al., 2003; Prajapati *et al.*, 2005; Zaridah *et al.*, 2006; Knio *et al.*, 2008). However, few studies were reported on the insecticidal effects of monoterpenes against mosquitoes. For example, Kim *et al.* (2008) stated that 1-8-cineole and camphene had larvicidal activity against *C. pipiens pallens*. It has been also found that some monoterpenes possessed toxic effect against *C. pipiens* (Radwan *et al.*, 2008). The larvicidal and anti-oviposition effects of pulegone, thymol and eugenol against *Aedes aegypti* L. were described (Waliwitiya, 2009). Moreover, some monoterpenes were shown to exhibit toxic effect towards *Ae. aegypti* L. and *Ae. Albopictus* (Cheng *et al.*, 2009). However, to the best of our knowledge, studies have not been conducted so far to evaluate the fumigant toxicity and growth and developmental effect of monoterpenes towards *C. pipiens*. The present investigation evaluated the comparative larvicidal activities, fumigant toxicities and developmental inhibitory effects of twelve monoterpenes against *C. pipiens*.

MATERIALS AND METHODS

1. **Insects:** A *Culex pipiens* L. (Diptera: Culicidae) colony maintained in the laboratory of Medical and Veterinary Insects, Department of Economic Entomology, for more than 10 years was used. Mosquitoes were held at 27±1 °C, 70±5% RH, and a photo regime of 14:10 (light:dark) hr. Adults were provided with a 10% sucrose solution as food source. A pigeon was introduced twice a week to the adults for blood feeding. Larvae were reared in dechlorinated water under the same temperature and light conditions and were fed daily with baby fish food.
2. **Chemicals:** Twelve monoterpenes, camphene (95%), (+)-camphor (98%), (−)-carvone (98%), 1-8-cineole (99%), cuminaldehyde (98%), (L)-fenchone (98%), geraniol (98%), (−)-limonene (96%), (−)-linalool (95%), (−)-menthol (98%), myrcene (90%) and thymol (98%) were purchased from Sigma–Aldrich Chemical Co., Steinheim, Germany. Chemical structures of these monoterpenes are shown in Fig. 1. Malathion (95%) was supplied by Kafr Elzayat Pesticides and Chemicals Co, Egypt and used as a reference insecticide. All chemicals were of highest grade commercially available.
3. **Larvicidal bioassay:** The larvicidal activity of the monoterpenes was evaluated on the fourth instar larvae of *Culex pipiens* by the method recommended by the World Health Organization (WHO, 1981) with some modification. Stock solutions of the tested monoterpenes were prepared in dimethyl sulfoxide (DMSO). Groups of 20 mosquito larvae were separately put into 200-ml plastic cups containing 100 ml of distilled water. The tested monoterpene solutions in 0.1 ml DMSO were added to each cup and suspended with Tween-20 (0.1 ml), with gentle shaking to ensure a homogeneous test solution. A preliminary test was conducted at concentrations of 10, 100 and 500 mg/l. Then a series of at least eight concentrations (from 10 to 500 mg/l) for each compound was tested. The control was prepared with distilled water containing the same amount of DMSO and Tween-20 as the test sample. Five replicates for each concentration and control

treatment were curried out. Treated and control larvae were held at the same conditions as used for colony maintenance. Larval mortalities were recorded 24 and 48 hr post-treatment. Larvae were considered dead when they did not respond to stimulus or did not rise to the surface of the solution. Mortality data were subjected to probit analysis to estimate the lethal concentration values (LC_{50}) of monoterpenes (Finney 1971).

4. **Fumigant toxicity bioassay:** The toxicity of the monoterpenes vapors against two-day old adults of *Culex pipiens* was examined. Glass jars of 0.4 liter capacity with tightly screw caps were used as exposure chambers during the fumigation test. The monoterpenes were applied on Whatman no. 1 filter paper pieces (3×3 cm) attached to the undersurface of screw caps of the glass jars at concentrations of 10, 50 and 100 mg/l (air). The solid monoterpenes were dissolved in acetone before treating the filter paper pieces and liquid monoterpenes applied directly to filter paper. After evaporation of acetone for two minutes, the caps were screwed tightly onto the jars containing 10 mosquito adults. Similar treatment without monoterpenes was served as control. Three replicates of each treatment and control were set up. The number of dead insects and mortality percentages were determined after 24 and 48 hrs of treatment.
5. **Growth and development bioassay:** Three monoterpenes, (−)-limonene, (−)-carvone, cuminaldehyde (98%), were tested for their effects on the development and the life cycle of *Culex pipiens*. The monoterpenes were evaluated at 0.5 LC_{50} values that were determined in larvicidal assay previously described. Solutions were prepared as described for larvicidal bioassays. Egg rafts were counted and transferred into 300-ml plastic vessels containing 200 ml of the test solution. One egg raft (~120 eggs) was used for each replicate. Three replicates for each compound and control treatment were carried out. The experiment was kept under the standard rearing conditions. After 7 days of treatment, the total number of larvae that emerged from the eggs was counted. The number of dead larvae was recorded every day throughout the larval developmental stages. Larvae were fed during the experiments. The formed pupae were recorded daily until all larvae turned to pupae in treatments and control (14 days). The number of emerged adults was counted for 13 days after the first adult emergence. The percentages of hatchability, larval mortality pupation and adult emergence were calculated.
6. **Data Analysis:** The concentration-mortality data of larvicidal assay

were subjected to Probit analysis to obtain the LC_{50} values using the SPSS 12.0 software program (Statistical Package for Social Sciences, Chicago, IL, USA). The values of LC_{50} were considered significantly different, if the 95% confidence limits did not overlap. Percentages of adult mortality in fumigant assay, and egg-hatchability, larval mortality, pupation, emerged adults and the total of mosquitoes completed their life cycle were analyzed by one-way analysis of variance (ANOVA). Mean separations were performed by Student–Newman–Keuls (SNK) test and differences at P = 0.05 were considered as significant.

RESULTS AND DISCUSSION

1. Larvicial activity of monterpenes:

The toxicity of 12 tested monoterpenes and malathion to the fourth-instar larvae of *C. pipiens* was evaluated on the basis of the LC_{50} values. The LC_{50} values, 95% confidence limits and other parameters generated from regression lines of the tested monoterpenes are shown in Table 1. Among the twelve monoterpenes screened, 9 compounds showed larval toxicity. Geraniol (LC_{50} = 38.56 mg/l) and cuminaldehyde (LC_{50} = 38.94 mg/l) were significantly the most potent compounds after 24 hr of treatment without significant differences (95% confidence limits overlap). Cuminaldehyde was significantly the most toxic compound after 48 hr of treatment, followed by geraniol and thymol with LC_{50} values of 21.38, 32.85 and 46.00 mg/l, respectively. Three monoterpenes, (−)-carvone, (−)-limonene, (−)-menthol, revealed good toxic effect, while (L)-fenchone and (+)-camphor exhibited weak toxic effect. The least toxic compounds, showed mortality less than 50 % even at the highest concentration of 500 mg/l, were myrcene, (−)-linalool and 1-8-cineole, and were considered not active. The tested monoterpenes were less toxic to the larvae than a reference insecticide, malathion.

Control of larvae is the most effective method in mosquito management programs because they are limited to aquatic habitats and before they become annoying adults. The monoterpenes, namely geraniol, cuminaldehyde and thymol showed excellent larvicidal properties. All compounds had LC_{50} values under 100 mg/l (21.38 - 52.31 mg/l); therefore, these monoterpenes have potential as good mosquitocides. Previous literature indicates that the bioactivities of the majority monoterpenes evaluated in the present investigation against larvae of *C. pipiens* have not been documented. However, the larvicidal activity of 1-8-cineole and camphene was reported against

C. pipiens pallens (Kim *et al*., 2008). Similarly, Radwan *et al.* (2008) demonstrated that some of the tested monoterpenes had larvicidal activity against *C. pipiens*. On the other hand, the larval toxicities of some plant extracts, essential oils and phytochemicals against *C. pipiens* have been reported (Ju *et al*., 1998; Cao *et al*., 2004; Abdelgaleil, 2005; Traboulsi *et al*., 2005; Abdelgaleil 2006; Michaelakis, 2007).

Table (1): Comparative toxicity of monoterpenes against the fourth instar larvae of *Culex pipiens* after 24 and 48 hr of treatment

Monoterpene	Exposure time (hr)	LC_{50}[a] (mg/l)	95% Confidence limits		Slope ± S.E.[b]	Intercept ± S.E.[c]	(χ^2)[d]
			Lower	Upper			
Camphene	24	> 500					
	48	449.53	423.41	486.90	6.02 ± 0.90	- 15.98 ± 2.34	0.12
(+)-Camphor	24	>500					
	48	307.66	186.71	634.97	0.75 ± 0.12	- 1.88 ± 0.25	0.03
(-)-Carvone	24	132.40	124.62	141.26	10.52 ± 1.00	- 22.32 ± 2.10	0.01
	48	129.31	121.72	137.98	9.96 ± 0.98	- 21.03 ± 2.03	0.01
1-8-Cineole	24	> 500					
	48	> 500					
Cuminaldehyde	24	38.94	33.52	45.81	2.95 ± 0.25	- 4.69 ± 0.38	0.27
	48	21.38	19.16	24.88	4.63 ± 0.66	- 6.16 ± 0.81	0.14
(L)-Fenchone	24	360.31	336.62	393.52	5.65 ± 0.74	- 14.45 ± 1.85	0.54
	48	334.71	313.58	361.67	5.56 ± 0.70	- 14.03 ± 1.74	0.58
Geraniol	24	38.56	29.53	46.98	1.63 ± 0.19	- 2.58 ± 0.36	1.00
	48	32.85	24.67	40.40	1.70 ± 0.20	- 2.58 ± 0.37	5.14
(-)-Limonene	24	139.65	130.73	149.21	8.22 ± 0.79	-17.62 ± 1.69	0.00
	48	123.81	116.76	133.08	11.17 ± 1.34	-23.38 ± 2.74	0.00
(-)-Linalool	24	> 500					
	48	> 500					
(-)-Menthol	24	173.97	161.41	186.65	5.79 ± 0.53	- 12.98 ± 1.20	0.02
	48	156.57	145.12	168.01	6.02 ± 0.53	- 13.21 ± 1.19	0.15
Myrcene	24	> 500					
	48	> 500					
Thymol	24	52.31	39.92	59.36	4.42 ± 0.92	- 7.69 ± 1.71	0.16
	48	46.00	43.53	48.28	8.98 ± 0.86	-14.94 ± 1.46	2.31
Malathion	24	0.0022	0.0018	0.0027	2.03 ± 0.20	5.38 ± 0.57	0.73
	48	0.0016	0.0014	0.0019	1.90 ± 0.20	5.31 ± 0.55	1.66

[a] The Concentration causing 50% mortality.
[b] Slope of the concentration-mortality regression line.
[c] Intercept of the regression line.
[d] Chi square.

2. Fumigant toxicity of monoterpenes:

The results of fumigant toxicity assay revealed that all of the tested monotrepenes possessed toxic effect to the adults of *C. pipiens* (Table 2). The toxicity of monoterpenes strongly enhanced with the increase of concentrations tested and the exposure times. At the lowest concentration (10 mg/l), (−)-carvone and geraniol were the most toxic with mortality percentages of 73.3 and 66.7% after 24 hr, and 80 and

96.7% after 48 hr, respectively. The monoterpenes of camphene, linalool and 1-8-cineole were the less effective ones at this concentration at both exposure times. The mortality percentages caused by monoterpenes increased at concentration 50 mg/l comparing with 10 mg/l with (−)-carvone and geraniol and being the most effective at 24 hr exposure time. These two compounds also caused complete mortality of mosquito adults at a concentration of 100 mg/l after 24 hr of treatment. All of the tested compounds showed high mortality percentages after 48 hr of treatment with 100 mg/l except for camphene, linalool and 1-8-cineole. Total mortality of *C. pipiens* adults was obtained for 100 mg/l doses of (−)-carvone, geraniol, menthol and camphor and (−)-limonene after 48 hr exposure.

The results of fumigant toxicity experiments indicate that test monoterpenes possess remarkable toxicity towards the adults of *C. pipiens*. Among the tested monoterpenes, five compounds, namely geraniol, (−)-carvone, (−)-menthol, (−)-limonene, (+)-camphor revealed promising toxicity. These compounds caused mortalities higher than 50% at the lowest concentration (10 mg/l) after 24 hr of exposure. Moreover, four of these compounds induced total mortality of the mosquito adults at 100 mg/l after 48 hr of exposure. This interesting activity may considered as starting point for using monoterpenes as fumigants for control mosquito adults in closed areas. To the best of our knowledge, the fumigant toxicity of the tested monoterpenes was not previously demonstrated against the adults of *C. pipiens*. However, it has been found that thymol and (−)-menthol had fumigant toxicity against the adults of *C. quiquefasciatus* (Samarasekera *et al.*, 2008). On the other hand, some essential oils isolated from Egyptian and Chinese plants have been shown to possess fumigant toxicity against the adults of *C. pipiens* (Yang *et al.*, 2005; El-Aswad and Abdelgaleil 2008).

Table 2: Mortality percentages for the adults of *Culex pipiens* after 24 and 48 hr of exposure to monoterpene vapors at different concentrations

Monoterpene	Mortality (%) ± SE[a]					
	10 mg/l		50 mg/l		100 mg/l	
	24hr	48hr	24hr	48hr	24hr	48hr
Camphene	10 ± 5.81 d	13.3 ± 3.36e	16.7± 6.71cd	26.7± 3.36b	33.3 ± 6 71c	40 ± 5.81c
(+)-Camphor	53.3 ± 8.88ab	63.3 ± 3.36bc	66.7± 8.88ab	86.7± 8.88a	90± 5.81a	96.7± 3.36a
(-)-Carvone	73.3 ± 6.71a	80 ± 5.81ab	86.7± 8.88a	96.7± 3.36a	100 ± 0.0a	100 ± 0.0a
1-8-Cineole	13.3 ± 3.36cd	16.7 ± 3.36e	23.3 ± 3.36cd	36.7 ± 8.88b	36.7 ± 6.71c	50 ± 5.81c
Cuminaldehyde	20 ± 5.81cd	23.3 ± 3.36de	40 ±5.81bc	43.3 ± 8.88b	60 ±5.81b	73.3 ± 5.81b
(L)-Fenchone	50 ± 5.81ab	56.7 ± 6.71bc	66.7 ± 6.71ab	73.3 ± 8.88a	90 ± 5.81a	96.7 ± 3.36a
Geraniol	66.7 ± 8.88 a	96.7 ± 3.36a	83.3 ± 8.88a	93.3 ± 3.36a	100 ± 0.0a	100 ± 0.0a
(-)-Limonene	60 ± 5.81ab	63.3 ± 6.71bc	66.7 ± 12.1ab	73.3 ± 8.88a	96.7 ± 3.36a	100 ± 0.0a
(-)-Linalool	16.7 ± 8.88cd	23.3 ± 3.36de	26.7 ± 8.88cd	33.3 ± 3.36b	43.3 ± 6.71c	56.7 ± 8.88c
(-)-Menthol	63.3 ± 3.36ab	70 ± 11.63b	80 ± 10.07a	90 ± 5.81a	96.7 ± 3.36a	100 ± 0.0a
Myrcene	36.7 ± 6.71bc	40 ± 5.81cd	63.3 ± 8.88ab	73.3 ± 8.88a	86.7 ± 3.36a	93.3 ± 3.36a
Thymol	50 ± 5.81ab	56.5 ± 8.88bc	66.7 ± 8.88ab	76.7 ± 6.71a	96.7 ± 3.36a	96.7 ± 3.36a
Control	0 ± 0.0d	0 ± 0.0c	0 ± 0.0d	0 ± 0.0c	0 ± 0.0d	0 ± 0.0d

[a] Means within each column followed by the same letter are not significantly different ($P = 0.05$).

3. Effects of monoterpenes on growth and development of *C. pipiens*

The effects of the tested monoterpenes at a concentration of 0.5 LC_{50} on mortality, growth and development of different stages of *C. pipiens* were monitored continuously starting from egg laid to adult emergence. The results of hatchability tests showed that (−)-carvone and (−)-limonene caused significant decreasing in the mean number of hatched eggs with hatchability percentages of 64.7 and 89.4, respectively (Fig. 2). In this test, cuminaldehyde had no significant effect on egg hatchability. The same time, (−)-carvone, (−)-limonene and cuminaldehyde showed remarkable toxicity to the emerged larvae with cuminaldehyde (80.2%) being the most potent one (Fig. 3). The tested compounds also significantly decreased the mean number of pupae comparing with the control (Fig. 4). It was found that (−)-carvone and cuminaldehyde delayed the beginning of pupation three days comparing with the control. At the end of pupation stage, control treatment completed pupation at day 10, while in cuminaldehyde treatment, the pupation completed at the day 13 and in case of (−)-carvone and (−)-limonene, the pupation completed at the day 14 (Fig. 5). The number of emerged adults was drastically decreased in the three tested monoterpene treatments comparing with control (Fig. 6). (−)-Limonene and cuminaldehyde showed the most potent effect on decreasing the emerged adults, since they induced 14.5 and 15.1% adult emergence, respectively.

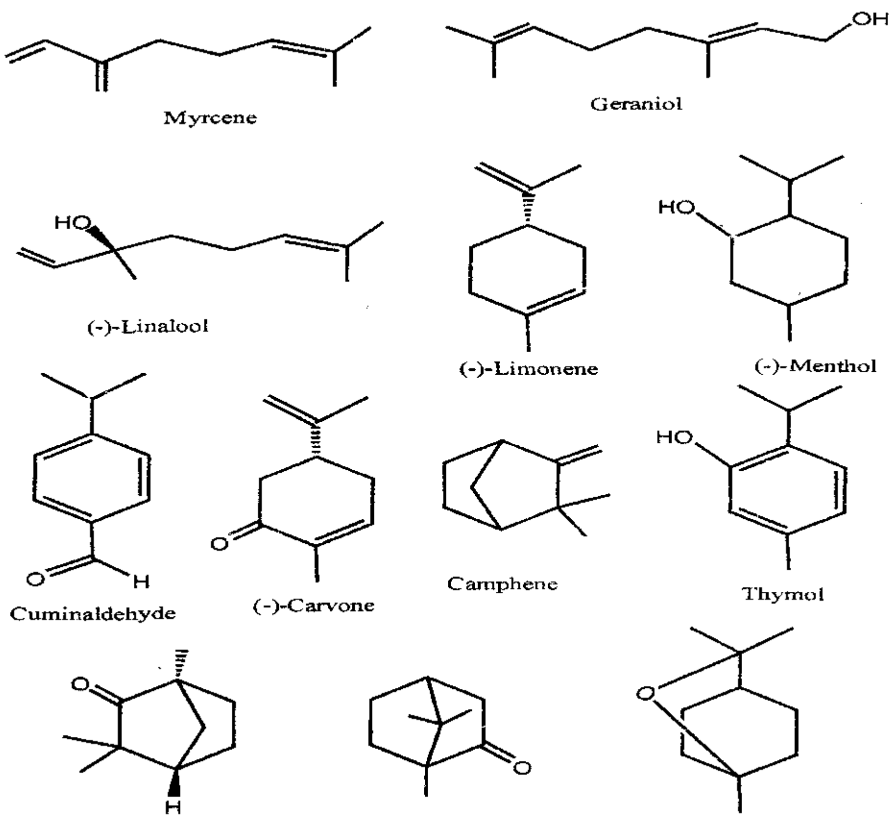

Fig. 1. The chemical structures of monoterpenes.

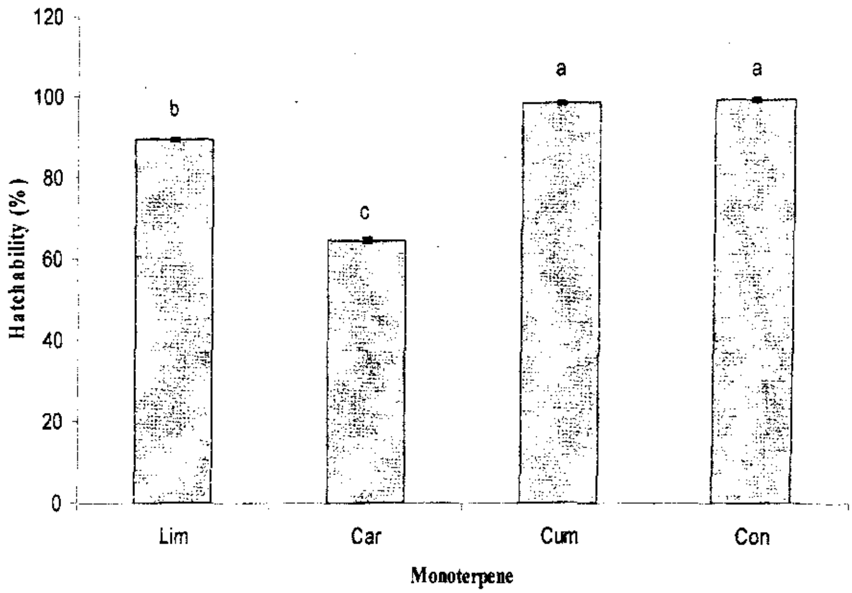

Fig. 2. Effect of monoterpenes on egg hatchability of *Culex pipiens* at concentration of 0.5 LC_{50}. Error bars represent the standard errors of the mean of three replicates. Bars headed by different letters are significantly different (P = 0.05). Student-Newman-Keuls (SNK) test was preformed on the data. Lim = (-)-Limonene,Car = (-)-Carvone, Cum = Cuminaldhyde, Con = Control.

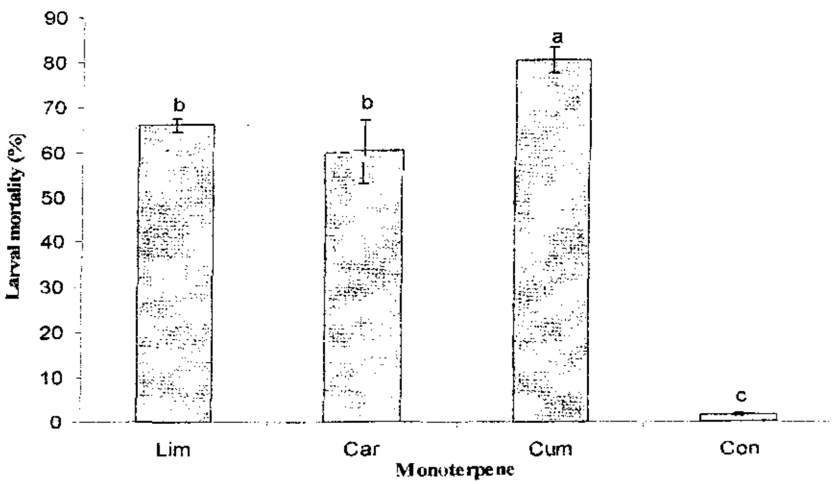

Fig. 3. Effect of monoterpenes on larval mortality of *Culex pipiens* at concentration of 0.5 LC_{50}. Error bars represent the standard errors of the mean of three replicates. Bars headed by different letters are significantly different (P = 0.05). Student-Newman-Keuls (SNK) test was preformed on the data. Lim = (-)-Limonene, Car = (-)-Carvone, Cum = Cuminaldhyde, Con = Control.

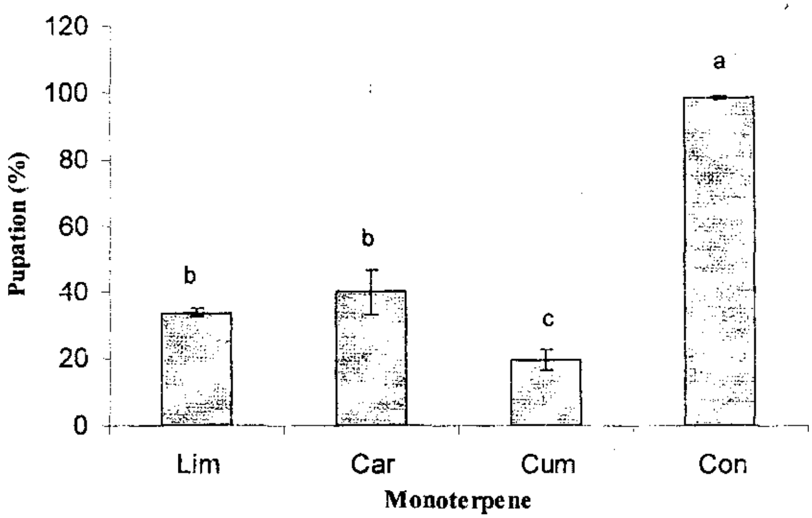

Fig. 4. Effect of monoterpenes on pupation percentages of *Culex pipiens* at concentration of 0.5 LC_{50}. Error bars represent the standard errors of the mean of three replicates. Bars headed by different letters are significantly different ($P = 0.05$). Student-Newman-Keuls (SNK) test was preformed on the data. Lim = (-)-Limonene, Car = (-)-Carvone, Cum = Cuminaldhyde, Con = Control.

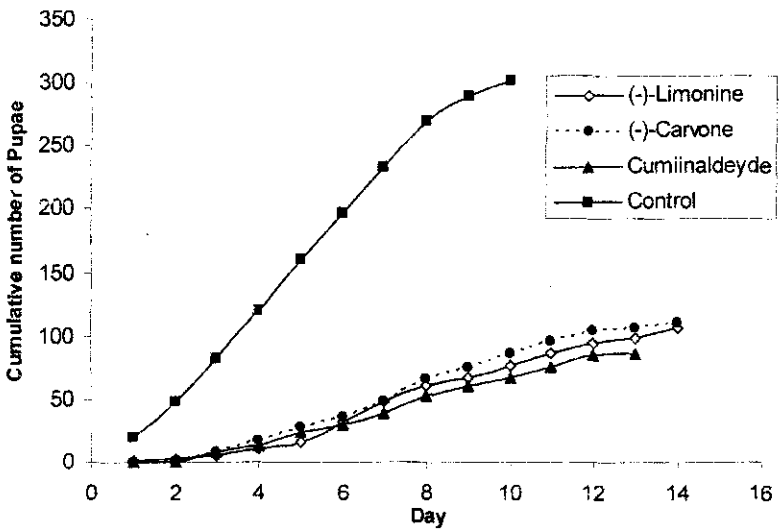

Fig. 5. Effect of monoterpenes on cumulative number of pupae of *Culex pipiens* at concentration of 0.5 LC_{50} during 14 days of pupation period.

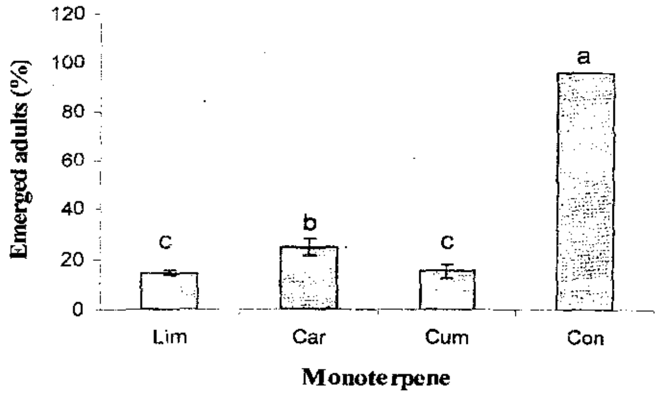

Fig. 6. Effect of monoterpenes on emerged adult percentages of *Culex pipiens* at concentration of 0.5 LC_{50}. Error bars represent the standard errors of the mean of three replicates. Bars headed by different letters are significantly different (P = 0.05). Student-Newman-Keuls (SNK) test was preformed on the data. Lim = (-)-Limonene, Car = (-)-Carvone, Cum = Cuminaldhyde, Con = Control.

The continuous exposure of *C. pipiens* to (−)-limonene, (−)-carvone and cuminaldehyde at sublethal concentration (0.5 LC_{50}) had a great effect on the development of the insect. For examples, the egg hatchability was strongly decreased, particularly in the treatment with (−)-carvone. The three momoterpenes caused high larval mortality and lowered pupation. The most interesting finding was that 14.5 and 15.3 % (emerged adults) of insects completed their life cycle in the treatment with (−)-limonene and cuminaldehyde, respectively. This indicates that these compounds have a good potential to control *C. pipiens* even at lower concentrations.

The structure-activity relationship investigation of the test compounds revealed that geranial, an alcohol, and cuminaldehyde, an aldehyde, showed the highest larval toxicity in larvicidal tests. Similarly, it has been found that both compounds were the most toxic among the tested monoterpenes against the adults of *Sitophilus oryzae* (Abdelgaleil *et al.*, 2009). A ketone ((−)-carvone) and geranial were the most active fumigant toxicants against the adults of *C. pipiens*. Nevertheless, Rice and Coats (Rice and Coats, 1994) found that some ketones were more effective fumigants than alcohols. The modes of toxic action of monoterpenes are not clearly known. However, it has been reported that some monoterpenes had inhibitory effect on acetylcholinesterase activity (Miyazawa *et al.*, 1997; Ryan and Byme, 1998; Picollo *et al.*, 2008). Moreover, some researchers reported that monoterpenes showed good binding with octopamine receptors (Enan,

2001) and GABA-gated chloride ion channel (Hold *et al.*, 2000).

The present study demonstrates the possibility for using the test monoterpenes as larvicides and fumigant toxicants against *C. pipiens*, particularly geranial, cuminaldehyde and (−)-carvone. It also indicates that the two later compounds and (−)-limonene have strong effect on the development of the insect and drastically reduced the adult emergence at sublethal concentrations. The effect of these monoterpenes at low concentrations is very helpful to reduce the chemical residues and environmental pollution. The diverse activities of the tested monoterpenes warrant further research into their potential development as compounds for mosquito control.

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التأثير الإبادى الحشرى والتأثير المثبط للنمو لمركبات المونوتربينات ضد حشرة البعوض الكيولكس بيبينز.

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فى هذه الدراسة تم تقييم النشاط الإبادى الحشرى لـ ١٢ مركب من المونوتربينات على يرقات العمر الرابع والحشرات الكاملة لبعوضة الـ *Culex pipiens* . مركبى Geraniol و Cuminaldehyde أظهرا أعلى سمية ضد اليرقات حيث كانت قيم الـ LC_{50} هى ٣٨,٥٦ و ٣٨,٩٤ مجم/لتر على الترتيب بعد ٢٤ ساعة، فى حين كان الـ Cuminaldehyde أعلى المركبات فاعلية بعد ٤٨ ساعة يليه Geraniol ثم Thymol . فى تجارب التدخين على الحشرات الكاملة مركب (−)-Carvone و Geraniol أظهرا أعلى سمية على جميع التركيزات المختبرة وزمنى التعرض. وعند أختبار المركبات على تركيزات نصف الجرعة المميتة ($0.5\ LC_{50}$) مركبات (−)-Carvone و (−)-Limonene و Cuminaldehyde سببت خفض معنوى فى نسبة فقس البيض و التعذير وخروج الحشرات الكاملة وكذلك سببت موت مرتفع لليرقات. النتائج المتحصل عليها من هذه الدراسة تشير إلى أن مركبات Geraniol و Cuminaldehyde و (−)-Carvone لها سمية جيدة ضد بعوضة *Culex pipiens* وربما تكون مفيدة فى البحث عن مبيدات حشرية طبيعية جديدة.