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Chemical Constituents and Insecticidal Effects of Jojoba and Lavender Essential Oils Against the Coconut Mealybug, *Nipaecoccus nipae* (Maskell), (Hemiptera: Pseudococcidae)

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Abstract: Botanical essential oils were exhibited pesticidal activities against many insects including mealybugs. The current study's objective was to evaluate the effectiveness of three concentrations of jojoba (*Simmondsia chinensis* (Link) C.K. Schneid) belongs to the family Simmondsiaceae and lavender (*Lavandula angustifolia* Mill) belongs to the Labiatae family essential oils on the populations of nymphs and adults of the mealybug *Nipaecoccus nipae* (Hemiptera: Pseudococcidae) under laboratory conditions after 24, 48 and 72 hrs. Additionally, analyzes and determines the chemical constituents of the two essential oils using GC-MS analysis. The results showed that the essential oils of jojoba and lavender were recorded high toxic effects against *N. nipae* after 72hrs.with the same lethal concentrations LC_{50} values at 192.07and 192.07ppm for nymphs populations, respectively. In the case of *N. nipae* adults, the LC_{50} values were 140.87 and 131.29ppm for jojoba and lavender essential oils after the same time, respectively. At the highest concentration (1000ppm), the percentages of *N. nipae* nymphs and adults mortality recorded the highest mortality percentage (100 and 96.67%) for jojoba essential oil and (100.00 and 100.00%) for lavender essential oil after 72hrs. of treatment, respectively. Mealybug mortality was increased by increasing of the period of exposure and the concentrations of oil. Both essential oils were proved to be very toxic to *N. nipae* nymphs and adults. The GC-MS analysis results revealed that seventeen components were found in jojoba essential oil and representing 98.89% of essential oil compositions. These compounds mainly consisted of two fatty acids Eicos-11-enoic acid (Gadoleic acid) (36.90%) and Arachidic acid (Eicosanoic acid) (24.68%) as major constituents. Other major compounds were 9-Octadecenal (6.17%), Glycerol triacetate (4.44%), while thirty two chemical compounds representing 99.94% of the lavender essential oil and the most abundant components were Linalyl acetate (27.46%), Linalool (26.29%), Caryophyllene (6.62%), and lavandulyl acetate (5.78%)and others components such as Caryophyllene oxide (5.04%) (Z)-β-Ocimene (4.77%)and Eucalyptol (3.27%).These fatty acids and monoterpenes compounds present in jojoba and lavender essential oils may responsible for the highly insecticidal activities against *N. nipae*. Our research indicates that the jojoba and lavender essential oils can be beneficial as botanical insecticide for an IPM strategy to mealybugs and protect crops against their attacks.

Key words: Essential oils, *Simmondsia chinensis*, *Lavandula angustifolia*, *Nipaecoccus nipae*, Bioassay, Gas Chromatography-Mass Spectrometry.

INTRODUCTION

Coccoidea superfamily includes all hemipteran members and consists of 28 families, is commonly known as mealybugs or coccids. The most significant family among them is Pseudococcidae, which distinguished by waxy secretions. Mealybugs of Pseudococcidae family are tiny, soft, oval bodied and sap-sucking insects of the Hemiptera family, feed on nearly 149 plant species and nearly 246 families of different plants and are commonly found infesting the leaves, branches, and roots of their host plants **(Portilla and Cardona 2004** and **Estopà *et al*., 2016)**, also, are major pests in ornamental gardens and agriculture (**Hollingsworth 2005** and **Palma-Jiménez *et al*., 2019)**. Among other fruit plants, they can feed on grape, coffee, pineapple, cotton, and citrus trees as food. Additionally, they can infest a variety of ornamental plants, including palm trees (**Daane *et al*. 2012 and Santa-Ceclia and Silva, 2020**).

Nipaecoccus nipae (Maskell), a novel polyphagous pest of economically significant agricultural crops (Fruit crops and ornamentals), and known as the coconut mealybug, that attacks 43 families of 80 genera of plants, including grapes, figs, avocados, citrus, cocoa, coconuts, guavas, mangoes, oil palms, orchids, pawpaws, pineapples, and citrus. (**Ben-Dov, 1994**). It has been discovered all over the world, including in America, Europe, Asia, Australia, and Africa (**Ben-Dov, 1994**). The coconut mealybug, *N. nipae*, is known by a number of names due to the diversity of hosts it infested, but coconut mealybug is the most common (**Espinosa *et al*., 2009**). Damage symptoms of this pest include the yellowing, vigour loss, and discoloration of the roots at the site of feeding, followed by the drying out of such roots (**Mohan *et al*., 2022**).

These phytophagous insects in agroecosystems are challenging to manage because of their small bodies and enigmatic personalities. Currently, the fundamental management technique is the use of synthetic pesticides (**Daane *et al*., 2012)**. The continuing use of synthetic pesticides not only breeds pest resistance but also exacerbates the agricultural crisis, which has an effect on ecosystems, natural resources, and the health of rural populations and urban consumers. (**Fantke *et al*., 2012).** Due to these negative consequences, it is now more important than ever to develop new, effective insecticides that are also environmentally friendly. Different researches have suggested certain essential oils (EOs) produced from plantsource, as safer natural substitutes to synthetic insecticides in this context (**Peschiutta *et al*., 2018, Campos *et al*. 2019** and **Damalas and Koutroubas 2020).**

The goal of this research is to use a spray technique method to examine the effects of jojoba, *Simmondsia chinensis* Link (Simmondsiaceae), and lavender, *Lavandula angustifolia* Mill (Labiatae), essential oils (EOs), on the mealybug *N. nipae* in laboratory conditions. The chemical costituents of these two EOs was also identified and estimated using gas chromatography-mass spectrometry analysis.

MATERIALS AND METHODS

1. Test insect

The coconut mealybug, *N. nipae* (Maskell), was the insect mealybug used in this investigation. It came from Poinciana plants (*Delonix Poinciana* regia) that were found in the Orman Garden in the Giza Governorate. Samples were collected at random from each of the four cardinal points (East, West, North and South). The leaves were transported to the lab in paper bags and maintained there at a temperature of approximately 25°C±5 and 65°RH (Relative Humidity) then to the scale insects and mealybug's taxonomy department, Plant Protection Research Institute, Agriculture Research Center, Giza, Egypt. The coconut mealybug nymphs and adults stages were chosen to test the insecticidal action of two essential oil formulations.

2. Plant materials

Jojoba seeds (*S. chinensis*) were purchased from the National Research Center, Dokki, Egypt, Natural Oils Unit and lavender fresh flowers (*L. angustifolia*), was bought from the herbal and vegetable store in Cairo, Egypt. The samples were identified at Botany Department - Faculty of Sciences-Cairo University-Egypt.

3. Extraction and preparation of formulated essential oils

3.1. Extraction of jojoba oil

In a hot air oven set to 60°C, jojoba seeds were weighed and dried until they reached a constant weight. By using the Soxhlet method, the crude oil content was determined by **Agarwal *et al*. (2018)**. Briefly, after being finely pulverized using a grinder, 20 g of jojoba seeds were extracted using the Soxhlet apparatus with petroleum ether (30-40 °C) as the solvent. For complete solvent evaporation, the extracted oil was left at room temperature for 24-48 hours.

3.2. Extraction of lavender oil

Using the **Cavalcanti *et al*. (2004)** method and essential oil was extracted from lavender flowers. Essential oil was extracted from the freshly sections by hydrodistillation in a Clevenger-type apparatus (Winzer, Wertheim, Germany) for 4 hours at 100°C (200g weight of each sample in 400 ml of distilled water). Following oil extraction, anhydrous sodium sulphate was used to dry the oils. They were kept in airtight containers or dark glass tubes and kept at 4°C until they were employed in analytical and bioassay tests.

4. Bioassay technique

Two essential oils (jojoba and lavender) were examined for toxicity against the mealybug insect *N. nipae* (nymphs and adults) using the leaf spraying method. The leaves of the poinciana tree that weren't infested were selected and placed in 9 cm diameter, 1 cm high, and 3.5 cm diameter petri dishes. Ten nymphs and ten adults of mealybugs were set on each leaf in Petri dishes after *N. nipae* individuals were removed from the infected Poinciana leaves and put in a container after being transported to the lab. After that, 1ml of each of our two natural essential oils in concentrations of 500, 750 and 1000 ppm was sprayed for five seconds onto each plate, leaf, and *N. nipae* individual. At room temperature; the dishes were permitted to dry while being covered. Three replicates of each treatment were used. We used Petri plates, which were then kept in a lab conditions and examined for mortality at 24, 48, and 72 hrs. The emulsifier Triton X-100 was used to prepare three concentrations of formulated oils of the two plants. Triton-xs100 was used to treat only the control insects.

5. Jojoba and lavender EOs analysis using gas chromatography-mass spectrometry

A 30-meter-long, 0.25-millimeter-inside-diameter, 0.25-millimeter-thick HP-5MS column was installed in the GC with a split ratio of 10:1, a flow rate of 1 ml/min, an injection volume of 1µl and the following temperature protocol, hydrogen was used as the carrier gas in the analyses:4°C/min rise to 150°C and hold for six minutes;4°C/min rise to 210 °C and hold for one minute. 40°C for one minute. The detector and pump were maintained at 220°C and 280°C, respectively. With an ionization energy of 70 eV, a spectral range of m/z 50–900, and a solvent delay of 5.5 min, many components were identified by contrasting the spectrum fragmentation pattern with those found in the Wiley and NIST Mass Spectral Library data.

6. Statistics

The Abbott formula (**Abbott, 1925**) was used to calculate the mortality rate as a percentage. Using the LdP-line application, the LC_{50} values were calculated. ANOVA was used to analyze the experiment data statistically, and the means of all trials were compared using Duncan's Multiple Range Test (**Duncan, 1955**) at a $P_{0.05}$ thresholds.

RESULTS AND DISCUSSION

1. Toxicity of the two plant essential oils to the mealybug *N. nipae*

The two plant species (jojoba and lavender) EOs were examined for toxicity bioassays against nymphs and adults of *N. nipae*. Data of toxicity after 24,48 and 72 hrs., of exposure are presented in (Tables 1 and 2).

The maximum mortalities of nymphs and adults of mealybug *N. nipae* after24 hrs., of exposure were recorded by the highest concentration 1000 ppm essential oil of jojoba (86.67±3.33 and 86.67±3.33%, respectively) and lavender essential oil (90.00±0.00 and 90.00±0.00%, respectively), while, after 48 hrs., the high mortalities of jojoba and lavender essential oils were (96.67±3.33 and 93.33±3.33%) and (96.67±3.33 and 93.33±3.33%), respectively with the same concentration. Both jojoba and lavender essential oils achieved the highest mortalities (100.00±0.00 and 96.67±3.33%) and (100.00±0.00 and 100.00±0.00%) against nymphs and adults of mealybug *N. nipae* after 72 hrs. However, approximately, the essential oils of jojoba and lavender showed 90-100% mortality of the *N. nipae* nymphs and adults at the three tested concentrations 500, 750,1000ppm after 72 hrs. The minimum mortalities values of jojoba and lavender essential oils were exhibited by the lowest concentration (500ppm) and recorded the following mortality percentages (66.67±3.33and 63.33 ±8.56) and (70.00±10.00and66.67±5.77%,), respectively for nymphs and adults after 24 hrs.

The results showed that jojoba and lavender essential oils presented considerably high insecticidal toxicity to the nymph and adults of the mealybug (*N. nipae*) at the three examined concentrations (500,750 and 1000ppm). Results of the lethal effects of the essential oils against nymphs and adults of *N. nipae* revealed significant differences between the different concentrations. Increasing of the concentrations from 500 to 1000 increased the nymphcidal and adultcidal mortality range from 66-100 %. The highest mortality values were observed at the highest concentration 1000ppm. According to the results, both essential oils exhibited a significant mortality of *N. nipae* nymphs and adults and in addition, this mortality response was concentration and time dependent (Tables 1 and 2).

Table (1). Insecticidal effect of Jojoba (*Simmondisa chinensis*) at three concentrations against nymphs and adults of coconut mealybug *Nipaecoccus nipae* (Maskell)

Conc. (ppm)	Mortality (Mean%±SE)					
	24 hour		48 hour		72 hours	
	Nymph	Adult	Nymph	Adult	Nymph	Adult
500	66.67±3.33^{b}	63.33±8.56^{b}	80.00±0.00^{b}	73.33±3.33^{b}	93.33±3.33^{a}	90.00±0.00^{a}
750	73.33±3.33^{b}	76.67±8.82^{a}	93.33±3.33^{a}	81.67±3.33^{ab}	100.00±0.00^{a}	93.33±3.33^{a}
1000	86.67±3.33^{a}	86.67±3.33^{a}	96.67±3.33^{a}	93.33±3.33$_{a}$	100.00±0.00^{a}	96.67±3.33^{a}
P	0.0230	0.0142	0.0156	0.0465	0.1111	0.1111
F	11.20	14.80	14.00	10.75	4.00	4.00

Table (2). Insecticidal effect of Lavender (*Lavandula angustifolia*) at three concentrations against nymphs and adults of coconut mealybug *Nipaecoccus nipae* (Maskell)

Conc. (ppm)	Mortality (Mean%±SE)					
	24 hour		48 hour		72 hours	
	Nymph	Adult	Nymph	Adult	Nymph	Adult
500	70.00±10.00^{b}	66.67±5.77^{c}	83.33±6.67^{a}	86.67±5.77^{a}	93.33±3.33^{a}	96.67±3.33^{a}
750	86.67±3.33^{a}	76.67±3.33^{b}	93.33±3.33^{a}	93.33±3.33^{a}	100.00±0.00^{a}	96.67±3.33^{a}
1000	90.00±0.00^{a}	90.00±0.00^{a}	96.67±3.33^{a}	93.33±3.33^{a}	100.00±0.00^{a}	100.00±0.00^{a}
P	0.1600	0.0026	0.2101	0.1111	0.1111	0.4444
F	3.00	37.00	2.36	4.00	4.00	1.00

Data in Table (3) demonstrated that, our results from the study showed that LC_{50}values of jojoba were (341.90, 286.67 and192.07 ppm) and (377.41, 303.36 and131.29 ppm), for nymphs and adults after 24, 48 and 72 hrs., respectively and LC_{90}values were (1316.16, 677.45and 443.32ppm) and (1220.93, 930.42 and481.34ppm), for the same two stages of mealybug after 24, 48and 72 hrs., respectively. While, results in Table (4) investigated that, LC_{50} of lavender was (309.24, 243.88 and192.07ppm) and (351.64, 217.14 and 140.87 ppm), for nymphs and adults after 24, 48 and 72 hrs., respectively and LC_{90} was (939.25,642.43 and 443.32 ppm) and (1092.64,581.43 and 427.41ppm), for the same two stages of mealybug after 24, 48and 72 hrs., respectively.

Table (3). Toxicological values (LC_{50} and LC_{90} ppm) of Jojoba essential oil on coconut mealybug *Nipaecoccus nipae* (Maskell)

Time (hrs.)	Toxicological values (LC_{50} and LC_{90} ppm)									
	LC_{50}			*LC_{90}*			*Slope*		*X^2*	
	Nymph	**Adult**	***Mean***	**Nymph**	**Adult**	***Mean***	**Nymph**	**Adult**	**Nymph**	**Adult**
24	341.90	377.41	359.65	1316.16	1220.93	1268.54	2.189	2.295	1.622	0.270
48	286.67	303.36	295.01	677.45	930.42	803.93	3.494	2.633	0.011	1.127
72	192.07	131.29	161.68	443.32	481.34	462.33	3.528	2.269	0.741	0.742

Table (4).Toxicological values (LC_{50} and LC_{90} ppm) of Lavender essential oil on coconut mealybug *Nipaecoccus nipae* (Maskell).

Time (hrs.)	Toxicological values (LC_{50} and LC_{90} ppm)									
	LC_{50}			*LC_{90}*			*Slope*		*X^2*	
	Nymph	**Adult**	***Mean***	**Nymph**	**Adult**	***Mean***	**Nymph**	**Adult**	**Nymph**	**Adult**
24	309.24	351.64	330.44	939.25	1092.64	1015.945	2.656	2.603	0.661	1.186
48	243.88	217.14	230.51	642.43	581.43	611.93	3.047	2.997	0.006	0.548
72	192.07	140.87	166.47	443.32	427.41	435.365	3.528	2658	0,742	0.074

Results reported in Tables (3 and 4) showed that, jojoba and lavender EOs exhibited insecticidal activity against *N. nipae* Lavender EO was relatively more toxic with LC_{50} and LC_{90}values. Also, the corresponding Mean $LC_{50}$and LC_{90}values of both nymphs and adults were (161.68 and 462.33ppm) and (166.47and 435.365ppm), after 72 hrs., respectively indicated that, jojoba and lavender exhibited a significant degree of efficacy as an insecticide Tables, (3 and 4).

Our findings corroborated those of (**Salem *et al*., 2003)** showed that jojoba oil formulation was the most effective treatment against both leafhopper and white fly species, with LC_{50} values of 5.40% for *Bemisia tabaci* and 6.40% for *Empoasca discipiens*, respectively. Also, (**Soltan, 2020)** examined the effectiveness of two essential oils (moringa and jojopa) and cascade against the third, fourth, and fifth nymphal instars of various species of grasshoppers. The results showed that after 12-day post-treatment, jojopa oil had the greatest mortality percentage of all the treatments (96.00%) and could be effective for creating grasshopper-friendly IPM strategies. In the same line study of (**Heikal, 2018**) evaluated the effectiveness of certain plant extracts, including jojoba oil, against *Aphis gossypii* Glover on Cucumber var. *Cucumis sativus* L. throughout the 2015 and 2016 seasons**.** Jojoba oil was effective against A. gossypii and recorded reduction percentages 84.36 and 85.83%, during the two seasons respectively. Similar findings of (**Halawa *et al*., 2007)** who showed that, the highest mortality percentage (100%) of Schistocerca gregaria nymphs was recorded at 10% jojoba oil and LC_{50} of jojoba oil was 2.2%. Both antifeedant and protection activity percentage were increased by increasing the concentration of jojoba oil at all treatments and (**Hamouda and Abd-Alla, 2022)** reported that, Jojoba oil has an acaricidal effect on *Tetranychus urticae* adult female mortality, at concentrations of 1000, 10,000and 100,000 ppm. Several studies were exhibited that jojoba essential oil has insecticidal effect on different economic pests and can be considered as an antifeedant, growth, development inhibitors and oviposition inhibitors such as *Spodoptera littoralis* **(Gaaboub *et al*., 2012)**, Pectinophora gossypiella nubilalis (**Hanady *et al*., 2020)**, *Callosobruchus maculatus* (F.). **(Helaly 2018)** and *Agrotis ipsilon* (**El-Shewy 2018)**.

Our results of insecticidal efficacy flavender EO are consistent with those of **(Digilio *et al*., 2008)** who revealed that, with a mortality rate of 100% following exposure to 2 l/L in air, L. angustifolia EO shown significant toxic effectiveness against two species of aphid pests of the chili and bean, Myzus persicae and Acyrthosiphon pisum (**Sayada *et al* ., 2021)** indicated that, depending on the concentration and exposure time, the essential oil of lavender, *L. angustifolia*, was exhibit insecticidal action against *Rhyzopertha dominica* (**El Abdali *et al***., **2022)** examined the toxicity of *L. dentata* essential oil (EO) from Moroccan lavender against adult *C. maculates*.

In experiments including contact and inhalation, lavender EO significantly reduced insect mortality, oviposition, and rate of emergence. In the study of (**Alkan *et al*., 2021)** the insecticidal of EOs obtained from lavender cultivars were tested against *Sitophilus granarius*. The experiment's findings indicate that these oils have a great deal of potential as pesticides.

2. Essential oils (EOs) Chemical Composition

GC/MS analysis was used for identified and determined the chemical composition of EOs obtained from jojopa and lavender oils (Tables 5 and 6) and (Figure 1 and 2).

2.1. Chemical Composition of jojoba essential oil (JEO)

Table (5) and Figure (1) showed the GC-MS analysis of jojoba essential oil which showed the presence of seventeen compounds, representing 98.99% of total oil composition. The essential oil consists of fatty acids (74.75%), esters (10.59%), aldehydes (6.17%) and alcohols (4.02%). Eicos-11-enoic acid (Gadoleic acid or gondoic acid), the main component of essential oil (36.90%), followed by eicosanoic acid (Arachidic acid) which was (24.68%). Other components identified in oil were 9-Octadecenal (6.17%), Triacetin (Glycerol triacetate) (4.44%), oleic Acid (4.34%), myristic acid (3.50%), 10-Octadecenoic acid, methyl ester (3.43%) and Hexadecanoic acid, methyl ester (2.72%). The class of volatiles with the highest representation was fatty acids (74.75%). Eicos-11-enoic and Eicosanoic acid were the most predominant of them. The second-largest chemical class investigated was esters (10.59%). Generally, gadoleic and arachidic acids were reported as the vital jojoba oil's main ingredients.

These results are in agreement with several studies of Egyptian jojoba oil, which showed that, the majority of the straight chain monoesters in jojoba oil have two double bonds and are alcohols and acids with molecular weights between C20 and C22.According to (**El-Mallah** and **El-Shami, 2009)** oleic (C18:1), eicosenoic (C20:1), docosenoic (C22:1), and tetraecosenoic (C24:1) acids were found to be abundant in the fatty acid profile of Egyptian jojoba oil. Also, the main fatty acid was eicosenoic acid, which represented 60% of all the fatty acids while, oleic and docosenoic acids achieved 14.5% and 11.8%, respectively. Oleic C18:1, eicosenoic C20:1, and docosenoic C22:1 were present in high concentrations in the jojoba oil from the Arizona region, 10.80, 67.80, and 18.90%, respectively. While, Egyptian local jojoba oil had amounts of C18:1, C20:1, C22:1, and C24:1 totaling 14.50, 60.00, 11.80, and 1.60%, respectively (**Tonnet and Dunstone, 1984**) and (**Gad *et al*., 2021)** reported that jojoba oil contains several fatty acids, the major one was eicos-l1-enoic acid (71.3%) and other fatty acids were docos-13-enoic acid (13.60%) and octadec-9-enoic acid (10.1%), hexadecanoic acid (1.20%).

(**Awad *et al*., 2022)** showed, unsaturated omega-9 fatty acid gondoic acid (C20:1) is also referred to as gondoleic acid, when compared to the other fatty acids, it exhibits the largest percentage value, ranging from 67.85% to 75.50%, and serves as the fundamental fatty acid in 15 Egyptian jojoba seeds oils. This is consistent with (**Al-Qizwini *et al*., 2014)** who, discovered that Egyptian wax has higher quantities of the fatty acid Cis-11-Eicosaenoic acid (20:1) than JO from other parts of the world. According to the aforementioned, the genotype of the jojoba strain affected the fatty acid profiles of all examined jojoba oils. All jojoba seed oils had gadolic acid as their main fatty acid. Similar findings of the chemical composition of jojoba seed oils were reported by several studies in the other world regions such as, (**Wisniak *et al.*, 1987)**study revealed that jojoba oil has a high concentration of mono-unsaturated fatty acids, especially 11-Eicosenoic acid (Gondoic acid).The conclusion of (**Miwa, 1984)** exhibited that up to 97.00% of the liquid wax from jojoba oil is consists of a combination of esters of long-chain fatty alcohols and long-chain fatty acids and these esters contains cis-11-eicosenoic acid in amounts more than 70%.Jojoba oil (JO) was investigated by (**Perillo *et al*., 2005)**contain high amount ofCis-11-eicosenoic acid.

Table (5). GC-MS analysis of the essential oil of Jojoba plant

No.	RT	Compound Name	MW	Area (%)	MF
1	2.02	**n-Hexane**	86	1.51	C_6H_{14}
2	12.16	**Pentane, 3-methyl-**	86	1.46	C_6H_{14}
3	13.19	**Triacetin or Glycerol triacetate (triglyceride)**	218	4.44	$C_9H_{14}O_6$
4	16.51	**Myristoleic acid**	226	1.50	$C_{14}H_{26}O_2$
5	18.85	**Myristic acid**	228	3.50	$C_{14}H_{28}O_2$
6	21.63	**Unknown**	-	0.20	-
7	23.42	**Unknown**	-	0.19	-
8	26.30	**Hexadecanoic acid, methyl ester**	270	2.72	$C_{17}H_{34}O_2$
9	27.64	**9-Octadecenal**	266	6.17	$C_{18}H_{34}O$
10	29.58	**10-Octadecenoic acid, methyl ester**	296	3.43	$C_{19}H_{36}O_2$
11	30.81	**Octadec-9-enol**	268	2.31	$C_{18}H_{36}O$
12	31.35	**Heptadecanoic acid =margaric acid**	270	2.12	$C_{17}H_{34}O_2$
13	32.25	**cis-11-Octadecenol**	268	1.71	$C_{18}H_{36}O$
14	32.47	**Eicos-11-enoic acid =Gadoleic acid**	310	36.90	$C_{20}H_{38}O_2$
15	35.15	**Erucic acid**	338	1.71	$C_{22}H_{42}O_2$
16	35.82	**Arachidic acid = Eicosanoic acid**	312	24.68	$C_{20}H_{40}O_2$
17	37.64	**Oleic Acid**	282	4.34	$C_{18}H_{34}O_2$
		Total identification		**98.89**	
		Total Fatty acids		**74.75**	
		Total Esters		**10.59**	
		Total Aldehydes		**6.17**	
		Total Alcohols		**4.02**	
		Other compounds		**3.36**	

MF=Molecular formula **MW= Molecular weight**
RT=Retention time

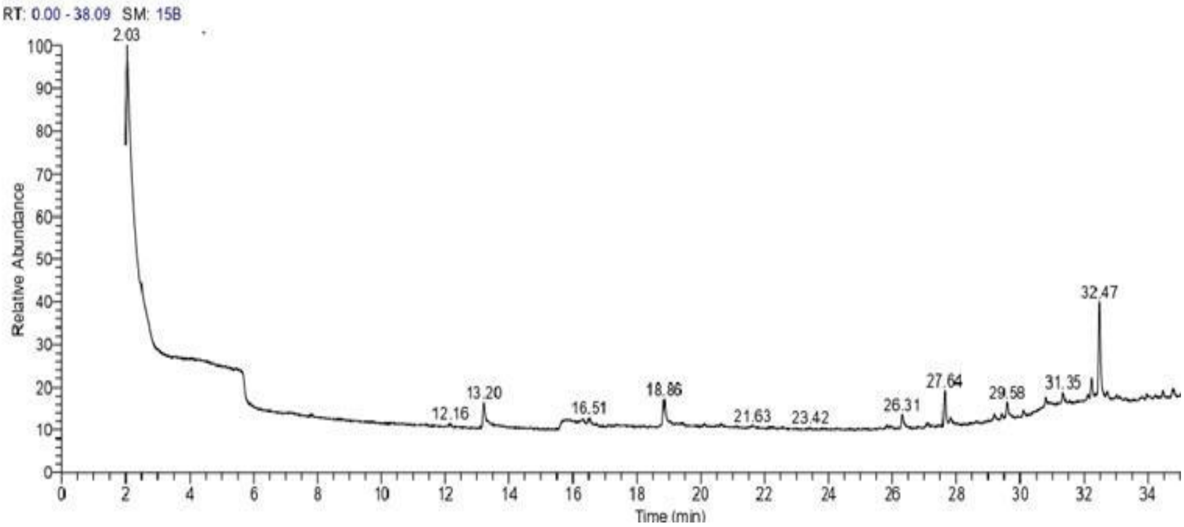

Figure (1). GC/MS Chromatogram of Jojoba, *Simmondsia chinensis* (Link) essential oil.

2.2. Chemical composition of lavenderessential oil (LEO)

The extracted essential oil from lavender flowers were identified and quantified by GC/MS, and the obtained chemical constituents are represented in Table (6) and Figure (2).The chemical composition of lavender oil, as shown, in Table (6), thirty two components were identified in lavender essential oil that represented 99.94% of the total volatiles constituents, (the total oil) andthe principle components were linalyl acetate (27.46%) and linalool (26.29%).Other identified compounds in lavender oil were caryophyllene (6.62%), lavandulyl acetate (5.78%), caryophyllene oxide (5.04 %), β-Ocimene (4.77%),eucalyptol(3.27%) andterpinen-4-ol (3.02%). Lavender EO consisted of high amounts of linalyl acetate (27.46%) and linalool (26.29%) which altogether represented about 55% of oxygenated monoterpene compounds identified. The main group of compounds are oxygenated monoterpenes (74.11%), Sesquiterpenes (13.89%) and Monoterpenes (9.28%).

Our findings full agree with those of (**Chen *et al*., 2020),** who found that the major constituents were linalyl acetate (28.9%), linalool (24.3%), caryophyllene (7.9%), trans-ocimene (4.6%),4-terpineol (4.0%), lavandulyl acetate (3.5%), borneol (2.6%) and eucalyptol (2.1%). The profile of Lavender EO in this investigation somewhat was comparable to that reported by (**Viuda-Martos *et al*., 2011)** who reported greater values for linalool (39.83%), linalyl acetate (32.11%), camphor (11.29%), and ß-phellandrene (7.63%) for lavender grown in Egypt. Our results are consistent with other studies such as, studies of (**Śmigielski, *et al*., 2011 and 2018)** revealed that, the chemical constituents of the essential oils extracted from both fresh and dried *L. angustifolia* flowers were examined, and the principal components were linalool (27.30 and 34.70%), linalyl acetate (22.40 and19.70 %), lavandulol acetate (5.70 and 4.50%), α-terpineol (4.60 and 5.10%) ,β-ocimene (2.90 and10.70%), a-terpineol (2.80 and 5.10%), geranyl acetate (2.60 and 2.30 %) and a-limonene (0.6 and 3.8%), respectively. The essential oil contained oxygenated monoterpenes (73.80 and 78.50%), sesquiterpenes (3.20 and 2.40 %) and oxygenated sesquiterpenes (3.40 and 3.20 %), respectively. Our findings partially agree study by **Pokajewicz *et al.* (2021)** demonstrated that the GC-MS analysis of the essential oil composition of fresh flowers from thirteen new Ukrainian cultivars of *L. angustifolia* revealed that the major components, linalyl acetate, linalyl geraniol, linalool, linalyl acetate, β-ocimene, terpinen-4-ol, and camphor ranged in concentration from 7.4% to 44.2% and 11.4% to 46.7%, respectively. Other recent studies on the essential oil of *L. angustifolia* revealed that it contains other components such as α-pinene, limonene, 1,8-cineole, cis-and trans-ocimene, 3-octanone, camphor, caryophyllene, terpinen-4-ol, lavendulyl acetate, and allo-aromadendrene. **(Council of Europe, 2020; Bejar, 2020** and **GOST ISO, 2021**). According to (**Prusinowska and Migielski, 2014)** the high concentration of linalool and linalyl acetate determines the lavender essential oil's quality. According to earlier study (**Hui *et al*., 2010**), the chemical composition of lavender oil is both qualitatively and quantitatively highly variable and depends on a variety of factors, including chemotypes, growing location, climatic conditions, propagation, morphological traits, cultivar, origin, plants' nutritional status, and many others.

Table (6). GC-MS analysis of the essential oil of Lavander plant

No.	RT	Compound Name	MW	Area (%)	MF
1	2.02	n-Hexane	86	0.25	C_6H_{14}
2	3.67	3-Carene	136	0.31	$C_{10}H_{16}$
3	3.95	Camphene	136	0.32	$C_{10}H_{16}$
4	4.43	(+)-β-Pinene	136	0.22	$C_{10}H_{16}$
5	4.50	3-Octanone	128	1.01	$C_8H_{16}O$
6	4.59	n-Hexyl acetate	144	0.74	$C_8H_{16}O_2$
7	5.00	β-Myrcene	136	0.73	$C_{10}H_{16}$
8	5.32	p-Cymene	134	0.18	$C_{10}H_{14}$
9	5.47	Eucalyptol	154	**3.27**	$C_{10}H_{18}O$
10	5.53	(Z)-β-Ocimene	136	**4.77**	$C_{10}H_{16}$
11	5.77	(E)-β-Ocimene	136	**2.75**	$C_{10}H_{16}$
12	6.34	cis-Linalool oxide	170	0.30	$C_{10}H_{18}O_2$
13	6.69	R(+)-Limonene	136	0.31	$C_{10}H_{16}$
14	7.08	Linalool	154	**26.29**	$C_{10}H_{18}O$
15	8.15	Camphor	152	0.42	$C_{10}H_{16}O$
16	8.62	Lavandulol	154	1.54	$C_{10}H_{18}O$
17	8.85	Borneol	154	1.18	$C_{10}H_{18}O$
18	9.05	Terpinen-4-ol	154	**3.02**	$C_{10}H_{18}O$
19	9.25	Butanoic acid, hexyl ester	172	0.41	$C_{10}H_{20}O_2$
20	9.46	α-Terpineol	154	2.10	$C_{10}H_{18}O$
21	10.20	cis-Geraniol(nerol)	154	0.36	$C_{10}H_{18}O$
22	10.80	Linalyl acetate	196	**27.46**	$C_{12}H_{20}O_2$
23	11.64	lavandulyl acetate	196	**5.78**	$C_{12}H_{20}O_2$
24	13.56	Neryl acetate	196	0.78	$C_{12}H_{20}O_2$
25	14.06	cis-Geranyl acetate	196	1.30	$C_{12}H_{20}O_2$
26	15.07	Caryophyllene	204	**6.62**	$C_{15}H_{24}$
27	15.40	trans-α-Bergamotene	204	0.24	$C_{15}H_{24}$
28	15.90	cis-α-Farnesene	204	0.72	$C_{15}H_{24}$
29	16.56	Germacrene D	204	0.97	$C_{15}H_{24}$
30	17.34	γ-Cadinene	204	0.30	$C_{15}H_{24}$
31	18.92	Caryophyllene oxide	220	**5.04**	$C_{15}H_{24}O$
32	29.44	8,11-Octadecadienoic acid, methyl ester	294	0.25	$C_{19}H_{34}O_2$
Total identified					**99.94**
Total monoterpenes					**9.28**
Total oxygenated monoterpenes					**74.11**
Total Sesquiterpenes					**13.89**
Other compounds					**2.66**

MF=Molecular formula **MW= Molecular weight** **RT=Retention time**

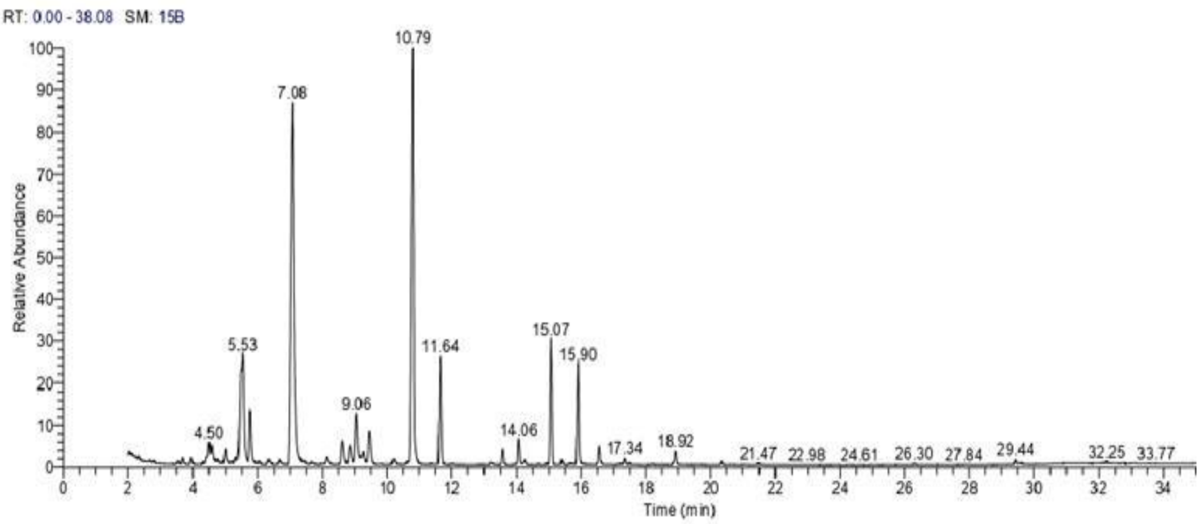

Figure (2). GC/MS Chromatogram of Lavander, *Lavandula angustifolia* Mill, essential oil.

While our findings showed that the oil of jojoba is primarily composed of fatty acids (74.75%), esters (10.59%), aldehydes (6.17%), and alcohols (4.02%), the mortality of *N. nipae* increased with the presence of the fatty acids. This mortality may be caused by the effect of fatty alcohols as well as hydrocarbons and sterols on the cuticle and/or by the disruption of the hormonal regulation caused by sterols and jojoba oil play a synergistic effect as antifeedant on insects **(Halawa *et al.*, 2007)**.

Although the mechanism of action of lavender essential oil against *N. nipae* insects was not explored, but according to (**Lopez *et al*., 2008)** terpene alcohol, linalool, or other terpene compounds may be to responsible for the toxicity of lavender oil to *N. Nipae*.Insecticidal effects of *L. angustifolia* EO against the *N. nipae* can be attributed to its main constituents, linalool, linalyl acetate, (Z)-β-Ocimene, lavandulyl acetate, caryophyllene, terpinen-4-ol andcaryophyllene oxide. Terpenoids including linalool, linalyl acetate, and caryophyllene, which impact the nervous system by inhibiting the action of the insect acetylcholinesterase enzyme (AChE) or changing ion transport, have been the subject of studies (**Digilio *et al*., 2008; Lopez and Pascual-Villalobos, 2010 and Shahriari *et al*., 2018).** Possibly also effect on respiratory system of insects (**Agarwal *et al.*, 1988**), or fumigant action via GABA-gated chloride channels **(Quarles, 1996).** These compounds and other minor compounds such as geraniol and geranyl acetate, all of which exhibited strong potency against insects of mealybugs, including *Phenacoccus solenopsis* **(Abasse, 2018)** *Pseudococcus jackbeardsleyi* (**Pumnuan and Insung, 2016**)**,** *Dysmicoccus brevipes* **(Martins *et al*., 2017)**, *Planococcus minor* **(Balfas, 2008)** *Planococcus citri* **(Erdemir and Erler, 2018)** *Drosicha mangiferae* **(Ghafoor *et al*., 2019)** *Maconellicoccus hirsutus* **(Holtz *et al*., 2021)** and *P. ficus* **(Karamaouna *et al*., 2013).**

Conclusions and recommendations

This search study the chemical composition of two plant essential oils (jojoba and lavender) and tested their insecticidal on nymphs and adults of *N. nipae* under laboratory conditions. Our findings revealed that in spray bioassays, jojoba and lavender; essential oils exhibited a toxic effect against *N. nipae* nymphs and adults. The compositional analysis of two oils indicated that mainly constituents of jojoba EO (Fatty acids) and two compounds of lavender EO (linalyl acetate and linalool) and other minor compounds may be responsible for the insecticidal activity of both essential oils and the reason of high potency of both oils to nymphs and adults of *N. nipae* can be used as an alternative to synthetic chemical insecticides.

This study shows the potential of jojoba and lavender essential oils as an insecticide IPM approach to manage *N. nipae* and in order to reduce the environmental damage caused by pesticides, more studies should be carried on jojoba and lavender essential oils to increase their effectiveness in controlling insect pests.

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