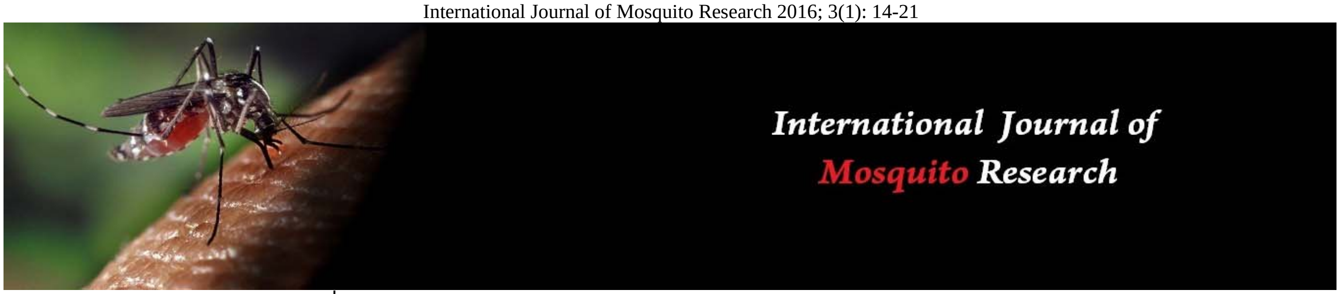

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Larvicidal and oviposition deterrent activity of twenty three essential oils against *Aedes aegypti*

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Abstract
Dengue and Chikungunya transmitted by *Aedes aegypti* cause more human mortality. Use of plant based chemical as insecticide are safe and alternative method as compared to synthetic chemicals for controlling dengue virus transmission. Twenty three essential oils were screened against *Ae. aegypti* under laboratory condition using larvicidal and ovipostion deterrent bioassay methods. In the result of larvicidal experiment, Litsea showed effective result at four concentrations *viz*., 10 mg/l, 50 mg/l, 100 mg/l and 500 mg/l with the value of LC_{50}: 46.775 (95% CI= 30.868 - 67.463). In the study of oviposition deterrent activity, litsea showed effective repellency was 33.83%, 71.47% and 87.17% at 10 mg/l, 50 mg/l and 100 mg/l respectively. These results indicated that the essential oil of Litsea served as effective larvicidal and oviposition deterrent activity against *Ae. aegypti*.

Keywords: Essential oils, larvicidal, oviposition, repellent, *Ae. aegypti*.

1. Introduction

A deadly disease such as malaria, dengue, chikungunya, yellow fever, and encephalitis is transmitted by *Anopheles*, *Aedes* and *Culex* and every year more than 700 million people are infected by these diseases [1]. Dengue fever and Dengue Haemorrhagic Fever (DHF) are the most common mosquito-borne viral diseases that affect a wide range of people more than 100 million people in the world and it is caused due to the bite of an infected species of *Aedes aegypti* [2] and dengue is prevalent in more than 100 countries and threatens the health of approximately 2.5 billion people [3]. *Ae. aegypti* is a small, dark mosquito with white markings and banded legs. Only the female bites for blood which she needs to mature her eggs. *Ae. aegypti* mosquito lives in urban habitats and breeds mostly in artificial and man-made containers. *Ae. aegypti* is a daytime feeder; its peak biting periods is early in the morning and before dusk in the evening [4].

The use of synthetic insect repellents, insecticides is highly effective and strong method for protecting, repelling and killing blood sucking mosquitoes. Insecticides play an important role in the preventing the vector-borne diseases by reducing man-vector contact. The “gold standard” repellent called DEET (N, N-diethyl-3-methylbenzamide also known as N, N-diethyl-m-toluamide) developed by US Army in 1953 are effective repellent against blood sucking insects but DEET is not only a good repellent also a toxic and also not safe for children and lactating women[5]. Transmission of deadly diseases are reduced or controlled by various methods such as repellent, insecticides, treated net, coil, liquid vaporizer etc and use of insecticide for controlling vector population is primary method and it is effective weapon but regular use of insecticides causes problem such as pollution, adverse effect on non target organism and insects develop genetically resistance power against these synthetic chemicals [6]. However, synthetic repellents have disadvantages including strong odours, skin irritation and possible health effects. Some repellents of synthetic origin may cause skin irritation and affect the dermis [7]. The discovery of DDT for mosquito control is completely based on synthetic organic insecticides and the existence use of this synthetic insecticide has resulted in environmental hazards and also in the development of physiological resistance in major vector species [8]. Therefore indeed for research and development of environmentally safe, biodegradable, low cost indigenous methods for vector control which can be used with minimum care by individual and communities in specific situation [9]. The use of plant origin does not pose hazards of toxicity to human, domestic animals and are easily biodegradable. Natural products are safe for human when compared to that of synthetic products [10, 11] and according to Kweka *et al.* [12] The plant products to reduce human vector contact are a common practice.

Essential oils a secondary complex form of highly volatile plant product and its aromatic quality play an alternative role use as an insecticidal and the phytochemical of essential oils contain various bioactive compounds which are useful for controlling vector borne diseases [13]. Many researchers reported the extract of essential oils from several parts of plant showed activity as repellent, insecticide, larvicide and oviposition-deterrent against various species of mosquito species [14]. First time pyrethrins were obtained from *Chrysanthemum* flowers as an effective pesticide and thus the industry of pyrethrin was born [15]. Essential oil is a complementary safe and biodegradable plant product use as a mosquito management program and the natural volatile substances known to have repellent property. However, plant-based products are still extensively used in the traditional way in rural communities for protection from mosquito [16].

The use of essential oils a plant based chemical contain allelochemicals or phytochemicals are safe, biodegradable, safe for non-target organism and also used as pesticides for many years against agricultural insects [17]. The synergistic effect of phytochemicals of plant based product showed different properties such as insecticidal, fungicidal, bactericidal, antiviral, antifeedant or insect growth inhibitor [18] and causes toxic effects on various insects [19]. Plant essential oils act as natural insecticides and also play important role for controlling vector borne diseases [20].

The present study was aimed to identify the effective essential oil for vector control with the help of larvicidal and oviposition activities against *Ae. aegypti* at various concentrations under laboratory conditions.

2. Material and Methods

2.1 Test Insect

The test mosquitoes *Ae. aegypti* were reared in the laboratory conditions in wooden cages (750 X 600 X 600 mm) for feeding and egg laying on a filter paper strip in a plastic container/bowl containing 250 ml of water. Cotton with 10% sugar solution was provided for nourishment and the female mosquitoes were fed on rabbits for blood meal initially for two days and then at every alternative days. The eggs were collected and transferred to a bowl containing two liters of water, for rearing of hatched larvae up to adult stage. Brewer's yeast powder was provided as food for larvae and water was changed on alternate days. The pupae were collected and kept in small cages (550 X 450 X 450 mm) covered with cotton cloth for emerging into the adult. *Ae. aegypti* (five to six days old) adults were drawn from the stock colony maintained at 27±2 ˚C and 70±5% RH for all the evaluations.

2.2 Essential Oils

Twenty three essential oils namely amyris (*Amyris balsamifera*), basil (*Ocimum basilicum*), black pepper (*Piper nigrum*), camphor (*Cinnamomum camphora*), catnip (*Nepeta cataria*), chamomile (*Anthemis nobilis*), cinnamon (*Cinnamamomus zeylanicum*), citronella (*Cymbopogon winterianus*), dill (*Anethum graveolens*), frankincense (*Boswellia carteri*), galbanum (*Ferula galbaniflua*), geranium (*Pelargonium graveolens*), jasmine (*Jasminum grandiflorum*), juniper (*Juniperus communis*), lavender (*Lavandula angustifolia*), lemon scented (*Eucalyptus citriodora*), lemongrass (*Cymbopogon citrates*), litsea (*Litsea cubeba*), peppermint (*Mentha piperita*), rosemary (*Rosmarinus officinalis*), rosewood (*Aniba rosaeodora*), tagetes (*Tagetes minuta* thyme (*Thymus serpyllum*) were obtained from the authentic source of trade / Fragrance and Flavour Development Center (FFDC), Kannauj (Uttar Pradesh).

3. Test Procedure and Methods.

3.1 Larvicidal Bioassay

The larvicidal experiment tested against third instar larvae of *Ae. aegypti* mosquito according to WHO protocol [21] with minor modification. Four concentration of stock solution 10 mg/l, 50 mg/l, 100 mg/l, 500 mg/l were prepared. For larval toxicity twenty 3rd instar larvae of *Ae. aegypti* were transferred in 250 ml of each glass beaker containing 100 ml tab water. For treatment 1ml of test solution was introduced in beaker and acetone served as a negative control. The test was replicated three times for each test concentration. After 1, 12, and 24 hour's total number of dead larvae in each beaker was counted.

3.2 Oviposition Deterrent Activity

Essential oils were evaluated at three concentrations such as 10 mg/l, 50 mg/l, 100 mg/l prepared in acetone and acetone served as a control. For oviposition support a filter paper strip was placed in internal surface of treated and control bowl of 500 ml capacity filled with 100 ml distilled water and the filter paper was half submerged in water. Twenty gravid *Ae. aegypti* female mosquitoes (5-7 days old) were released in a bioassay cage (60 x 60 x 45 cm). The bioassay was conducted in a laboratory using Xue *et al* [22] with slight modification. One milli litre solution from stock solution was dispensed in 100 ml of water and 1 ml acetone solution served as a control was used. After half an hour's treated and control bowl were placed diagonal position in bioassay cage. The eggs laid in each cup were counted daily after removal of the oviposition filter paper. Four replicates were performed for oviposition test.

3.3 Statistical Analyses

Effectiveness of the test oils was determined by comparing the 95% confidence intervals of the LC_{50} values and the values of effective LC_{50} were obtained through probit analysis and by use of POLO PLUS-PC 2.0 software. The oviposition activity index (OAI), was calculated using the following formula [23]. OAI= (NT-NC)/ (NT+NC). The percent effective repellency (ER %) for each essential oil was calculated in case of the test solution as a deterrent using the following formula [24]. ER%= (NC-NT)/ NC X 100. Where NT is the total number of eggs in the treated solution, and NC is the total number of eggs in the control solution. The OAI ranges from -1 to +1, with 0 indicating neutral response. The negative index values indicate that more eggs were deposited in the test bowl than in the control bowl, the test solutions were attractive. However, negative index value more eggs in the control bowl than in the test bowl and the test solutions were a deterrent. The data was analyzed by independent *t* test using statistical software (SigmaStat V2.03).

4. Results

4.1 Larvicidal Bioassay

In the present study, twenty three essentials oils were screened against third star larvae of *Ae. aegypti.* The result obtained from larvicidal activity and lethal dose of twenty three essential oils to *Ae. aegypti* shown in Table 1 and 2. Out of twenty three essential oils litsea exhibited least LD_{50} values ranging from 46.775% (95% CI= 30.868 - 67.463) followed by rosewood with LD_{50} 57.8% (95% CI= 43.428 - 76.078) and juniper with LD_{50} values ranging from 276.076% (95% CI= 190.498 - 465.987) against *Ae. aegypti* larvae. The result indicated that litsea oil most effective promising. However, geranium showed LD_{50} 61.154 % (95% CI= 40.180 - 91.205) followed by lemon scented and lemongrass with LD_{50} 70.711 % (95% CI= 46.097 - 108.466) and 79.711 % (95% CI= 60.629 - 105.769), respectively.

4.2 Oviposition Deterrent Bioassay

The result obtained from the oviposition deterrent of twenty three essential oils to *Ae. aegypti* shown in Table 3. The present results showed that the different concentrations of essential oils reduced number of eggs deposited by gravid females *Ae. aegypti* of treatment at 10 mg/l, 50 mg/l and 100 mg/l concentrations. The range of mean number of eggs laid in twenty three essential oils at three different concentrations 10 mg/l, 50 mg/l and 100 mg/l of litsea showed effective results are 225.00 ± 12.21, 91.00 ± 3.03 and 65.25 ± 7.81 eggs per bowl respectively and showed significant difference with controls (P<0.05) and the least result of eggs laid by *Ae. aegypti* mosquito showed by juniper are 265.75 ± 9.01, 252.00 ± 4.49 and 177.50 ± 7.47 eggs per bowl at 10 mg/l, 50 mg/l and 100 mg/l concentration respectively showed significant difference with controls (P<0.05). The effective repellency percentage was showed by litsea against oviposition was 33.83% in 10 mg/l, 71.47% in 50 mg/l and 87.17% in 100 mg/l concentration. However, The range of oviposition activity index of litsea at three concentrations (10 mg/l, 50 mg/l and 100 mg/l) paired with control ranged from -0.2 to -0.8 and the lowest percentage of effective repellency was showed by juniper against oviposition was -99.44% in 10 mg/l, 24.00% in 50 mg/l and 48.96% in 100 mg/l concentration. Likewise, the range of oviposition activity index of juniper at three concentrations (10 mg/l, 50 mg/l and 100 mg/l) paired with control ranged from 0.3 to -0.3 and the result showed that gravid *Ae. aegypti* females preferred to lay eggs in control bowl as well as treated bowl with respect to treated bowl and control bowl.

5. Discussion

Plant contains chemical compounds such as alkaloids, terpenoids, tannins and essential oils which are used as a defence purpose against herbivorous, other insects and having anti-insect property [25]. Essential oils are highly volatile and bioactive compound with high volatile vapour toxicity against mosquito and also contain biologically active agents which are responsible for repelling mosquito and more than 2000 plant species showed insecticidal activity [15]. According to Tawatsin *et al* [26]. The property of essential oil depend on various factors are species, cultivating conditions, maturation of harvested plants, plant storage, extraction method and volatility. Essential oils have effective chemicals causes combined effect of repellent activity against mosquito and all essential oils contain combination of different chemical compounds having different repellent property and the effective chemicals are responsible for repelling gravid females for egg laying because gravid female mosquito are highly sensitive towards volatile compounds and repellent product as compared to host seeking mosquitoes [27]. *Ae. aegypti* find oviposition site mainly fresh water container and gravid female move away from the breeding site without laying egg from oviposition repellent site [28a-28b].

In the present study of larvicidal activity, litsea oil exhibited effective larvicidal property as compared to twenty three essential oils. However, another species *Litsea salicifolia* showed effective pesticides activity against *Ae. aegypti* mosquitoes [29] and *Litsea cubeba* and *Litsea salicifolia* showed larvicidal activity against *Anopheles arabiensis*, *Anopheles gambiae* and *Culex quinquefasciatus* [30]. Manimaran *et al* [31]. Reported that some essential oils namely calamus, cinnamon, citronella, clove, eucalyptus, lemon, mentha and orange exhibited 100% larvicidal and knockdown activities against *Culex quinquefasciatus*. However, according to Amer and Mehlhorn [32] camphor, thyme, lemon, cedorwood, cinnamon, eucalyptus, menthe, citronella, geranium, lemongrass showed larvicidal activity against *Ae. aegypti*.

In the present result of essential oils oviposition deterrent activity against *Ae. aegypti* gravid female mosquito showed promising results such as litsea showed effective result with significance differences between tested and control by paired t-test (P< 0.05) in comparison of twenty three essential oils. The OAI range of litsea from -0.2 to -0.8 values indicated that the test solutions were deterrents at the range of 10mg/l to 100mg/l. Likewise, rosewood and geranium also showed effective OAI range with negative value from -0.2 to -0.7 and 0.1 to -0.7 respectively with significance differences tested and control (P< 0.05). The negative and positive value of oviposition activity index (OAI) showed in table 3, the positive index values (+) indicated that the test solutions were attractant, the negative index values (–) indicated that the test solutions were deterrents and 0 indicating neutral response.

The effective oviposition deterrent could be useful for mosquito control programmes against mosquitoes [33]. Identification of phytochemicals from plant uses as effective repellent, deterrent, insecticide etc. against deadly mosquitoes for mosquito vector management program are useful for making effective eco-friendly, safe, biodegradable, nontoxic and safe for non-targeting organism as compared to synthetic chemicals.

Table 1: Larval mortality percentage of 3rd instar larvae of *Ae. aegypti* exposed for 24 hours to different concentrations of 23 essential oils

compound	Concentration	Mortality % 1 hr	Mortality % 12 hrs	Mortality % 24 hrs
		Mean ± SE	Mean ± SE	Mean ± SE
Amyris	10 mg/l	0 ± 0	0 ± 0	3 ± 0
	50 mg/l	0 ± 0	6 ± 0.59	11 ± 0.34
	100 mg/l	5 ± 0.34	8 ± 0.34	23 ± 0.68
	500 mg/l	15 ± 0	23 ± 0.9	49 ± 0.68
Basil	10 mg/l	0 ± 0	3 ± 0	1 ± 0
	50 mg/l	0 ± 0	15 ± 0.59	14 ± 0.68
	100 mg/l	4 ± 0.34	24 ± 0.59	21 ± 1.02
	500 mg/l	15 ± 0	36 ± 0.59	40 ± 1.7

Black pepper	10 mg/l	0 ± 0	3 ± 0	1 ± 0
	50 mg/l	0 ± 0	6 ± 0.59	11 ± 0.34
	100 mg/l	4 ± 0	16 ± 0.34	22 ± 0.34
	500 mg/l	13 ± 0.34	28 ± 0.34	49 ± 0.34
Camphor	10 mg/l	0 ± 0	2 ± 0.34	3 ± 0
	50 mg/l	0 ± 0	6 ± 0	13 ± 0.34
	100 mg/l	5 ± 0.34	12 ± 0	21 ± 0
	500 mg/l	15 ± 0	21 ± 0	47 ± 0.34
Catnip	10 mg/l	0 ± 0	3 ± 0	4 ± 0.34
	50 mg/l	0 ± 0	12 ± 0	17 ± 0.34
	100 mg/l	8 ± 0.34	21 ± 0	20 ± 0.68
	500 mg/l	21 ± 0.59	30 ± 0	43 ± 0.9
Chamomile	10 mg/l	0 ± 0	0 ± 0	1 ± 0.34
	50 mg/l	0 ± 0	7 ± 0.34	11 ± 0.34
	100 mg/l	7 ± 0.34	18 ± 0	23 ± 0.68
	500 mg/l	16 ± 0.34	26 ± 0.34	44 ± 0.34
Cinnamon	10 mg/l	0 ± 0	3 ± 0	1 ± 0.34
	50 mg/l	0 ± 0	8 ± 0.34	9 ± 0
	100 mg/l	8 ± 0.34	25 ± 0.34	26 ± 0.34
	500 mg/l	17 ± 0.34	30 ± 0	49 ± 0.34
Citronella	10 mg/l	0 ± 0	2 ± 0.34	2 ± 0.34
	50 mg/l	0 ± 0	9 ± 0	19 ± 0.34
	100 mg/l	12 ± 0	21 ± 0	21 ± 0
	500 mg/l	18 ± 0.59	27 ± 0	49 ± 0
Dill	10 mg/l	0 ± 0	1 ± 0.35	7 ± 0.34
	50 mg/l	0 ± 0	5 ± 0.34	14 ± 0.68
	100 mg/l	16 ± 0.34	13 ± 0.34	23 ± 0.34
	500 mg/l	27 ± 0.59	22 ± 0.34	42 ± 0
Frankincense	10 mg/l	0 ± 0	2 ± 0.34	1 ± 0
	50 mg/l	0 ± 0	6 ± 0	12 ± 0
	100 mg/l	6 ± 0	18 ± 0	23 ± 0.68
	500 mg/l	14 ± 0.34	27 ± 0	48 ± 0.59
Galbanum	10 mg/l	0 ± 0	2 ± 0.34	2 ± 0.34
	50 mg/l	0 ± 0	7 ± 0.34	16 ± 0.68
	100 mg/l	7 ± 0.34	22 ± 0.34	29 ± 0.59
	500 mg/l	22 ± 0.34	28 ± 0.34	47 ± 0.34
Geranium	10 mg/l	0 ± 0	0 ± 0	6 ± 0
	50 mg/l	0 ± 0	11 ± 0.34	11 ± 0.34
	100 mg/l	3 ± 0	18 ± 0.59	24 ± 0
	500 mg/l	7 ± 0.34	22 ± 0.34	43 ± 0.34
Jasmine	10 mg/l	0 ± 0	1 ± 0.34	1 ± 0.34
	50 mg/l	0 ± 0	6 ± 0.59	10 ± 0.34
	100 mg/l	11 ± 0.9	17 ± 0.34	22 ± 0.34
	500 mg/l	49 ± 0.9	27 ± 0	41 ± 0.34
Juniper	10 mg/l	0 ± 0	0 ± 0	1 ± 0.34
	50 mg/l	0 ± 0	0 ± 0	12 ± 0
	100 mg/l	3 ± 0	14 ± 0.34	19 ± 0.7
	500 mg/l	12 ± 0.59	21 ± 0.59	36 ± 0.56
Lavender	10 mg/l	0 ± 0	0 ± 0	4 ± 0.34
	50 mg/l	0 ± 0	18 ± 0	10 ± 0.68
	100 mg/l	12 ± 0	27 ± 0	23 ± 0.68
	500 mg/l	23 ± 0.34	32 ± 0.34	47 ± 0.34
Lemongrass	10 mg/l	0 ± 0	3 ± 0	3 ± 0
	50 mg/l	0 ± 0	12 ± 0.59	14 ± 0.34
	100 mg/l	11 ± 0.34	11 ± 0.34	23 ± 0.68
	500 mg/l	37 ± 0.90	24 ± 0.59	47 ± 0.34
Lemon scented	10 mg/l	0 ± 0	4 ± 0.34	11 ± 0.68
	50 mg/l	0 ± 0	5 ± 0.34	20 ± 0.34
	100 mg/l	11 ± 0.90	13 ± 0.34	22 ± 0.34
	500 mg/l	22 ± 0.34	27 ± 0	46 ± 0.34
Litsea	10 mg/l	0 ± 0	0 ± 0	15 ± 1.02
	50 mg/l	0 ± 0	26 ± 0.34	30 ± 2.04
	100 mg/l	3 ± 0	37 ± 1.22	37 ± 2.72
	500 mg/l	7 ± 0.34	46 ± 0.34	53 ± 0.9

Peppermint	10 mg/l	0 ± 0	0 ± 0	3 ± 0
	50 mg/l	0 ± 0	18 ± 0.59	11 ± 0.34
	100 mg/l	11 ± 1.22	27 ± 0.59	22 ± 1.7
	500 mg/l	20 ± 0.9	39 ± 0.59	52 ± 0.34
Rosemary	10 mg/l	0 ± 0	3 ± 0	1 ± 0.34
	50 mg/l	0 ± 0	10 ± 0.34	15 ± 0
	100 mg/l	13 ± 0.34	17 ± 0.34	23 ± 0.68
	500 mg/l	25 ± 0.68	25 ± 0.68	39 ± 0
Rosewood	10 mg/l	0 ± 0	2 ± 0.34	7 ± 0.34
	50 mg/l	0 ± 0	18 ± 0	29 ± 0.34
	100 mg/l	14 ± 0.68	26 ± 0.34	37 ± 0.34
	500 mg/l	16 ± 0.34	48 ± 0.59	56 ± 0.34
Tagetes	10 mg/l	0 ± 0	0 ± 0	1 ± 0.34
	50 mg/l	0 ± 0	0 ± 0	9 ± 0
	100 mg/l	7 ± 0.34	21 ± 0.59	22 ± 0.34
	500 mg/l	11 ± 0.9	29 ± 0.34	43 ± 0.34
Thyme	10 mg/l	0 ± 0	3 ± 0	4 ± 0.34
	50 mg/l	0 ± 0	15 ± 0.59	12 ± 0.68
	100 mg/l	5 ± 0.34	24 ± 0.59	21 ± 0
	500 mg/l	16 ± 0.34	33 ± 0	47 ± 0.34
Acetone	10 mg/l	0 ± 0	0 ± 0	0 ± 0
	50 mg/l	0 ± 0	0 ± 0	0 ± 0
	100 mg/l	0 ± 0	0 ± 0	0 ± 0
	500 mg/l	0 ± 0	0 ± 0	0 ± 0

Table 2: 24hrs LC_{50} values (mg/l) and their 95% (upper and lower) limits and Chi-square (X^2) values of 23 essential oils for the 3rd instar larvae of *Ae. aegypti*.

Compound	LC_{50}	95% Lower Limit to Upper limit	Slope ± SEM	X2(df=2)
Amyris	150.163	113.965 - 207.077	1.590 ± 0.191	1.473
Basil	211.45	152.192 - 324.032	1.344 ± 0.183	1.418
Black pepper	150.414	116.834 - 200.540	1.787 ± 0.210	0.244
Camphor	144.667	106.509 - 207.992	1.374 ± 0.176	1.957
Catnip	181.684	83.22 - 841.283	1.397 ± 0.184	2.5976
Chamomile	181.96	136.794 - 256.994	1.559 ± 0.196	0.752
Cinnamon	149.744	116.871 - 198.170	1.835 ± 0.214	1.663
Citronella	136.499	65.034 - 421.862	1.526 ± 0.187	2.5981
Dill	103.57	63.002 - 187.972	0.772 ± 0.144	0.009
Frankincense	155.767	119.972 - 210.531	1.713 ± 0.205	0.106
Galbanum	129.655	97.622 - 178.628	1.496 ± 0.183	1.173
Geranium	61.154	40.180 - 91.205	0.999 ± 0.151	1.022
Jasmine	212.073	156.011 - 313.140	1.467 ± 0.192	1.143
Juniper	276.076	190.498 - 465.987	1.253 ± 0.182	1.241
Lavender	162.856	75.54 - 636.242	1.447 ± 0.180	2.6485
Lemon scented	70.711	46.097 - 108.466	0.951 ± 0.149	0.939
Lemongrass	79.711	60.629 - 105.769	1.567 ± 0.183	1.043
Litsea	46.775	30.868 - 67.463	1.082 ± 0.156	0.391
Peppermint	135.831	67.62 - 378.441	1.732 ± 0.200	2.7506
Rosemary	206.598	92.025 - 1281.667	1.285 ± 0.178	2.4703
Rosewood	57.8	43.428 - 76.078	1.556 ± 0.183	0.353
Tagetes	199.617	149.682 - 284.649	1.573 ± 0.199	0.994
Thyme	161.152	118.549 - 233.840	1.398 ± 0.177	1.367
Acetone	0	0	0	0

Table 3: Mean number of egg laying by gravid *Ae. aegypti* female and their oviposition activity index for 23 essential oils. Significant differences between tested and control by paired *t*-test ($P < 0.05$).

Compound	Conc.	Mean number of egg laying ± SE		OVI	ER	*t* test value
		Treated	Control			
Amyris	10 mg/l	226.25 ± 9.97	226.75 ± 23.76	0.0	0.22	0.985
	50 mg/l	186.50 ± 10.84	270.25 ± 13.28	-0.2	30.99	<0.001
	100 mg/l	140.25 ± 5.28	364.25 ± 11.61	-0.4	61.5	<0.001
Basil	10 mg/l	241.00 ± 5.40	244.00 ± 2.92	0.0	1.23	0.642
	50 mg/l	142.00 ± 15.67	304.75 ± 8.81	-0.4	53.4	<0.001
	100 mg/l	121.25 ± 15.40	358.75 ± 6.32	-0.5	66.2	<0.001

Black pepper	10 mg/l	257.75 ± 5.34	237.00 ± 28.53	0.0	-8.76	0.502
	50 mg/l	165.50 ± 9.13	299.00 ± 4.14	-0.3	44.65	<0.001
	100 mg/l	148.00 ± 3.54	365.00 ± 11.75	-0.4	59.45	<0.001
Camphor	10 mg/l	192.00 ± 2.55	227.25 ± 6.73	-0.1	15.51	0.003
	50 mg/l	167.25 ± 34.24	318.50 ± 17.83	-0.3	47.49	<0.001
	100 mg/l	122.50 ± 4.09	443.75 ± 32.59	-0.6	72.39	<0.001
Catnip	10 mg/l	185.75 ± 6.47	155.25 ± 14.09	0.1	-19.65	0.097
	50 mg/l	150.75 ± 3.33	340.75 ± 8.81	-0.4	55.76	<0.001
	100 mg/l	124.75 ± 5.47	442.25 ± 17.75	-0.6	71.79	<0.001
Chamomile	10 mg/l	208.75 ± 18.99	162.50 ± 17.29	0.1	-28.46	0.122
	50 mg/l	118.75 ± 10.84	256.50 ± 6.70	-0.4	53.7	<0.001
	100 mg/l	124.25 ± 4.96	316.75 ± 2.50	-0.4	60.77	<0.001
Cinnamon	10 mg/l	212.00 ± 8.06	225.25 ± 33.82	0.0	5.88	0.716
	50 mg/l	103.25 ± 3.35	286.25 ± 26.55	-0.5	63.93	<0.001
	100 mg/l	88.50 ± 3.93	345.00 ± 25.95	-0.6	74.35	<0.001
Citronella	10 mg/l	221.75 ± 4.52	271.25 ± 6.68	-0.1	18.25	<0.001
	50 mg/l	133.75 ± 11.33	362.50 ± 2.96	-0.5	63.1	<0.001
	100 mg/l	115.00 ± 7.52	423.75 ± 20.55	-0.6	72.86	<0.001
Dill	10 mg/l	230.00 ± 8.15	235.25 ± 6.18	0.0	2.23	0.626
	50 mg/l	131.50 ± 4.73	340.75 ± 11.55	0.0	61.41	<0.001
	100 mg/l	125.75 ± 0.85	434.25 ± 10.59	-0.6	71.04	<0.001
Frankincense	10 mg/l	241.50 ± 12.24	248.00 ± 5.05	0.0	2.62	0.641
	50 mg/l	148.00 ± 7.45	315.25 ± 27.51	-0.4	53.05	0.001
	100 mg/l	120.25 ± 3.52	392.75 ± 14.29	-0.5	69.38	<0.001
Galbanum	10 mg/l	236.50 ± 9.65	283.00 ± 12.61	-0.1	16.43	0.026
	50 mg/l	103.00 ± 0.71	329.50 ± 8.63	-0.5	68.75	<0.001
	100 mg/l	101.00 ± 2.68	486.00 ± 5.97	-0.7	79.22	<0.001
Geranium	10 mg/l	202.75 ± 8.28	246.00 ± 8.42	-0.1	17.58	0.011
	50 mg/l	104.75 ± 2.21	334.75 ± 23.77	-0.5	68.71	<0.001
	100 mg/l	77.50 ± 8.58	430.50 ± 18.54	-0.7	82	<0.001
Jasmine	10 mg/l	225.57 ± 4.09	221.75 ± 4.09	0.1	-15.22	0.001
	50 mg/l	185.50 ± 25.93	306.75 ± 31.11	-0.3	39.53	0.024
	100 mg/l	158.50 ± 4.66	309.50 ± 34.60	-0.3	50.08	0.004
Juniper	10 mg/l	265.75 ± 9.01	133.25 ± 4.68	0.3	-99.44	<0.001
	50 mg/l	252.00 ± 4.49	154.25 ± 9.08	0.2	24	0.006
	100 mg/l	177.50 ± 7.47	347.75 ± 30.47	-0.3	48.96	0.002
Lavender	10 mg/l	257.75 ± 4.75	230.25 ± 9.51	0.1	-11.94	0.041
	50 mg/l	130.25 ± 9.90	373.00 ± 7.69	-0.5	65.08	<0.001
	100 mg/l	107.25 ± 2.78	433.00 ± 10.60	-0.6	75.23	<0.001
Lemon scented	10 mg/l	211.50 ± 7.80	223.00 ± 23.57	0.0	5.16	0.66
	50 mg/l	103.00 ± 3.49	291.50 ± 37.74	-0.5	64.67	<0.001
	100 mg/l	93.50 ± 4.65	468.25 ± 7.58	-0.7	80.03	<0.001
Lemongrass	10 mg/l	209.50 ± 12.66	282.75 ± 20.86	-0.2	25.91	0.024
	50 mg/l	121.75 ± 5.22	316 ± 21.01	-0.4	61.53	<0.001
	100 mg/l	106.00 ± 5.60	480 ± 4.77	-0.6	77.95	<0.001
Litsea	10 mg/l	225.00 ± 12.21	340.00 ± 26.84	-0.2	33.82	0.007
	50 mg/l	91.00 ± 3.03	319.00 ± 13.20	-0.6	71.47	<0.001
	100 mg/l	65.25 ± 7.81	508.75 ± 16.54	-0.8	87.17	<0.001
Peppermint	10 mg/l	256.00 ± 4.14	266.25 ± 19.61	0.0	3.85	0.627
	50 mg/l	156.25 ± 4.15	279.00 ± 6.07	-0.3	44	<0.001
	100 mg/l	124.75 ± 0.63	450.50 ± 19.29	-0.6	72.31	<0.001
Rosemary	10 mg/l	255.00 ± 7.52	273.75 ± 11.06	0.0	6.85	0.211
	50 mg/l	143.25 ± 5.68	296.25 ± 5.14	-0.4	51.65	<0.001
	100 mg/l	117.25 ± 5.78	439.25 ± 8.34	-0.6	73.3	<0.001
Rosewood	10 mg/l	225.75 ± 6.79	332.75 ± 25.69	-0.2	32.16	0.008
	50 mg/l	101.25 ± 7.27	285.00 ± 32.21	-0.5	64.47	0.001
	100 mg/l	88.50 ± 5.39	491.75 ± 11.09	-0.7	82	<0.001
Tagetes	10 mg/l	265.50 ± 2.53	19.50 ± 22.32	0.2	-37.92	0.017
	50 mg/l	183.00 ± 6.14	259.00 ± 9.79	-0.2	29.34	<0.001
	100 mg/l	157.50 ± 3.71	380.00 ± 8.01	-0.4	58.55	<0.001
Thyme	10 mg/l	240.75 ± 3.04	205.25 ± 46.10	0.8	-17.3	0.471
	50 mg/l	142.25 ± 5.28	249.25 ± 11.30	-0.3	42.93	<0.001
	100 mg/l	132.25 ± 6.39	319.75 ± 3.71	-0.4	58.64	<0.001

The OAI ranges from -1 to +1; the positive index values (+) indicated that the test solutions were attractants; the negative index values (–) indicated that the test solutions were deterrents and 0 indicating neutral response

6. Conclusion
The present study showed that essential oils can provide larvicidal and deterrent activity against tested *Ae. aegypti* female mosquito. These results could encourage for developing new natural product from plants oil offering an alternative to synthetic products.

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