ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 11, Issue, 02, pp.1484-14889, February, 2019

DOI: https://doi.org/10.24941/ijcr.34298.02.2019

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

LARVICIDAL, OVICIDAL AND OVIPOSITION DETERRENT EFFICACY OF EXTRACTS OF TWO PLANT SPECIES AGAINST *CULEX QUINQUEFASCIATUS* SAY, AT MYSURU, INDIA

***Kumuda, S.S., Mohan Kumar, T.K. and Vijayan, V. A.**

Department of Studies in Zoology, Manasagangotri, University of Mysore, Mysuru – 570006, India

ARTICLE INFO

Article History:
Received 20th November, 2018
Received in revised form
14th December, 2018
Accepted 10th January, 2019
Published online 28th February, 2019

Key Words:

Larvicidal, ovicidal, Oviposition deterrent, *Culex quinquefasciatus, Dalbergia oliveri, Heracleum rigens*

**Corresponding author:*
Kumuda, S.S.

ABSTRACT

Background*:** Mosquito control has been facing problem mainly because of the development of resistance to chemical insecticides. Hence research on plant-based bioactive insecticides as parts of integrated vector management have received renewed attention. In this regard the present study was undertaken to assess the larvicidal, ovicidal and oviposition deterrent activity of different solvent extracts of *Dalbergia oliveri* leaves and *Heracleum rigens* seeds against *Culex quinquefasciatus*, the *Filariasis* vector in India. ***Material and methods*:* The larvicidal bioassay was conducted following the WHO method, Ovicidal and Oviposition deterrent activity tests were carried out following the method of Rajkumar and Jebanesan, (2009). ***Results*:** Results indicate that maximum larvicidal activity was found with the petroleum ether extract of both *D. oliveri* and *H. rigens* against the vector species with LC_{50} values being 36.28ppm and 69.25ppm respectively. In the ovicidal activity assay, the petroleum ether extract of *D. oliveri* and *H. rigens* produced 100% mortality at 100 ppm and 125ppm against *Cx. quinquefasciatus* eggs. Here the LC_{50} value for *D. oliveri* was 24.98ppm compared to 34.83ppm for *H. rigens*. Likewise in oviposition deterrent effect experiment, petroleum ether extract of both *D. oliveri* and *H. rigens* exhibited 100% activity at 50ppm and 125ppm with LC_{50} value 14.62ppm and 39.03ppm respectively. ***Conclusion*:** These investigations indicate that the leaf/seed extracts of local plants have the potential to be developed eco-friendly phyto molecules for vector control. Further, the results also pinpoint the superior efficacy of *D. oliveri.*

***Citation: Kumuda, S.S., Mohan Kumar, T.K. and Vijayan, V. A.* 2019.** "Larvicidal, Ovicidal and Oviposition deterrent efficacy of extracts of two plant species against *Culex quinquefasciatus* Say, at Mysuru, India.", *International Journal of Current Research*, 11, (02), 1484-14889.

INTRODUCTION

Many mosquito species are medically important vectors that transmit dreadful diseases such as malaria, Japanese encephalitis, Yellow fever, Dengue, Chikungunya, Lymphatic Filariasis, Zika virus etc. Vector-borne diseases have beena major problem to humans in tropical and subtropical regions. Therefore, WHO has declared the mosquitoes are "Public enemy number one" (WHO, 1996). The latest addition being Zika viral infection transmitted by *Aedes* mosquitoes in part of Africa and Caribbean islands. As such a major part of the national health, budget is spent on the control of vector-borne diseases especially in tropics. Thus it is imperative to control mosquitos in order to improve the public health (Appadurai *et al.,* 2015). Vector control should be the priority scheme as there are no effective vaccines or treatment against many of these diseases. As chemical insecticides are otherwise harmful to human and his environment alternative methods such as biological control and phyto chemicals are explored. Among mosquitoborne diseases in India, lymphatic filariasis is a disease affecting humans caused by nematode parasites *Wuchereria bancrofti* and *Brugia malayi.* Seventeen states and six Union Territories were identified to be endemic with about 553 million people exposed to the risk of infection; and of them, about 146 million live in urban and the remaining in rural areas (Sabeson *et al.,* 2010). Filariasis is estimated that around 20% of the world populations in more than 83 countries are at risk of acquiring infection which is 1.1 billion people (WHO, 2014). About 31 million people are estimated to be the carriers of mf and over 23 million suffer from filarial disease manifestations in India (ICMR, 2017). 2,245 newly diagnosed cases of lymphatic filariasis were recorded in 2016, including 132 cases of chronic filariasis with lymphedema. It is estimated to be endemic in over 250 districts in 20 states, putting 650 million people at risk. *Cx.quinquefasciatus* is the solitary vector of bancroftian filariasis in India. Mosquito control programs have suffered a setback, primarily because mosquito vectors have developed resistance to synthetic chemical insecticides. The use of synthetic insecticides, in the long run, produces negative effectssuch as biomagnification, soil and water pollution which have created many public health problems. Further, excessive mortality and reduced reproductive potential in birds, fish,and other organisms are reported (Elango *et al.,* 2009). Thus there is an obvious need for the development of alternative products to complement or even replace existing mosquito control strategies. In this regard potential botanicals are recognized as potent alternative insecticides to replace synthetic insecticides in mosquito control programs due to their excellent larvicidal, ovicidal, pupicidal and adulticidal properties with no known hazard to

the environment and to human health (Elango *et al.,* 2009). Plant extracts, essential oils, secondary metabolites and lectins from several plant species have been proved to function as a general toxicant, growth and reproductive inhibitor, insect repellent, larvicidal, ovicidal, oviposition deterrent against mosquito vectors (Khandagle *et al.,* 2011). In line with this trend, the present study was undertaken to investigate the larvicidal, ovicidal and oviposition deterrent activities of different solvent extracts of two local plants *Dalbergia oliveri* and *Heracleum rigens* against the filarial vector *Culex quinquefasciatus.*

MATERIALS AND METHODS

A few plant species were collected from Hassan District, Karnataka and identified those with larvicidal potential after preliminary experiments. As leaves of *D. oliveri* and seeds of *H. rigens* were found to be effective, these were dried under shade for 8-10 days at room temperature, powdered mechanically with the help of a laboratory hand blender. This powder was subjected for extraction with different solvents such as petroleum ether, ethyl acetate, chloroform, methanol and acetone using Soxhlet extractor to obtain the crude form. The extracts were allowed to dry and used for conducting preliminary larval bioassay. Larvae were procured from the colony maintained at Vector Biology Research Lab, Department of Zoology, University of Mysore, Mysuru.

Bioassay for larvicidal efficacy

The larvicidal efficacy of the two plant extract was evaluated as per the method of World Health Organization (WHO, 2005). Different concentrations of the extracts were prepared by serial dilutions of stock solution using acetone as solvent. Group of 25 early 4th instar larvae were released into the glass beakers containing 249ml dechlorinated tap water and 1ml of extract. The toxicity of each extract was determined with five different concentrations. The beakers contained 249ml dechlorinated tap water with 25 larvae and 1ml of acetone served as control. Control and test beakers were maintained at same conditions at 25±2ºC, 14:10 light and dark regime. No food was provided to the larvae till the mortality was monitored. All treatments were repeated four times. The larvae were considered as dead or moribund, if they were not responsive to gentle prodding with a fine needle.

Ovicidal activity assay

For ovicidal activity assay, the freshly laid eggs were collected by providing ovitraps in mosquito cages. Two days after the female mosquitoes were given a blood meal. The egg rafts were carefully removed from the piece of filter paper with a brush and exposed for 48h to different concentrations of test solution. Distilled water mixed with acetone served as control. A minimum of 100 eggs were used for each treatment, and the experiment was replicated four times. After treatment, the eggs were sieved through muslin cloth, thoroughly rinsed with tap water, and left in plastic cups filled with dechlorinated water for hatching assessment after counting the eggs under a microscope (Su *et al.,* 1998). The percent egg hatchability was calculated on the basis of non-hatchability of eggs with unopened opercula (Chenniappan and Kadarkarai, 2008). The hatching rate of eggs was assessed after 96 h post treatment as per the method of Rajkumar and Jebanesan (2009). The control mortality, if any was corrected using Abbott formula (Abott, 1925).

$$\text{Percent egg hatchability} = \frac{\text{Number of egg hatched}}{\text{Number of eggs released}} \times 100$$

$$\text{Corrected ovicidal activity (\%)} = \frac{\text{Larvae hatched in control(\%) - larvae hatched in treatment}}{\text{100 - Larva hatched in control (\%)}} \times 100$$

Oviposition deterrence assay

The oviposition deterrence efficacy of the two plant extract on egg laying capacity of *Cx. quinquefasciatus* was assessed by introducing 100 females and 100 males into cages (45×45× 40 cm) in a room at 27±2°C and 75–85% relative humidity with a photoperiod of 14:10 h light and dark cycles. Adults were provided with 10% sucrose solution in a plastic cup with a cotton wick. The mosquitoes were blood fed on day five after emergence. In this test five cups of 100ml capacity containing a different concentration of the extract for oviposition. The sixth cup without extract served as a control. The positions of the plastic cups were alternated between the different replicates so as to nullify any effect of position on oviposition. Four replicates for each concentration were run with cages placed side by side for each bioassay. After 48 h, the number of eggs laid in treated and control cups were counted under a stereomicroscope. The percent effective repellency for each concentration was calculated using the following formula (Rajkumar and Jebanesan, 2009).

$$ER\% = \frac{NC - NT}{NC} \times 100$$

Where,
ER=Effective repellency,
NC=Number of eggs in control,
NT=Number of eggs in treatment

The oviposition experiments were expressed as a mean number of eggs and oviposition activity index (OAI), which was calculated using the following formula.

$$OAI = \frac{NT - NS}{NT + NS}$$

Where,
NT=Total number of eggs in the test solution and
NS=Total number of eggs in the control solution.

Oviposition active index of +0.3 and above are considered as attractants while those with −0.3 and below are considered as repellents (Kramer and Mulla, 1979). Positive values indicate that more eggs were deposited in the test cups than in the control cups and that the test solutions were attractive. Conversely, negative values indicate that more eggs were deposited in the control cups than in the test cups and that the test solutions were a deterrent.

Data analysis

The analysis of larval mortality, egg hatchability, effective repellency data were subjected to Probit analysis for calculating LC_{50}, LC_{90}, at 95% confidence limits of upper confidence limit (UCL) and lower confidence limit (LCL), and chi-square values. The mean values and standard deviations were calculated from replicon data.

Table 1: Larvicidal activity of different solvent extracts of *Dalbergia oliveri* leaf*and Heracleum rigens* seedagainst*Culexquinquefasciatus*

Plant species	Solvents	LC_{50} ±SE (ppm LCL-UCL)	LC_{90}± SE (ppm LCL-UCL)	Regression equation	X^2 (df)	P-value
D.oliveri	Petroleum ether *	36.28± 0.147 (28.06-44.62)	60.61±0.147 48.22-117.28)	Y=5.7514X ±3.9706	15.21(3)	0.0001
	Ethyl acetate	94.56±0.065 (89.78-99.42)	155.74 ± 0.065 (144.05-172.28)	Y=5.9144X ±6.6852	2.11(3)	0.0001
	Chloroform	104.134 ± 0.066 (99.12-108.78)	159.62 ±0.066 (150.15-172.63)	Y=6.9088X ±8.9391	4.95(3)	0.0001
	Methanol	156.73 ± 0.064 (151.42- 161.71)	214.52 ±0 .064 (204.84- 227.82)	Y=9.4021X ±15.6391	1.81(3)	0.0001
	Acetone	169.69 ±0.1060 (154.25-185.340)	231.82 ± 0.1060 (206.70-299.72)	Y=9.4587X ±16.0898	8.38(3)	0.0001
H.rigens	Petroleum ether*	69.25± 0.161 (51.04-86.34)	114.51± 0.161 (90.64-235.53)	Y = 5.0207 X ± 4.8740	17.91(3)	0.0001
	Ethyl acetate	92.61 ± 0.103 (77.52-108.69)	116.69 ± 0.103 (134.87-267.98)	Y = 5.0207X ± 4.8740	8.02(3)	0.0001
	Chloroform	115.08 ± 0.062 (109.39-120.75)	191.02 ± 0.062 (176.00-273.516)	Y = 5.8200 X ± 6.9951	2.53(3)	0.0001
	Methanol	165.94± 0.064 (106.90-170.93)	224.02 ± 0.064 (213.86-237.98)	Y = 9.833 X ± 6.8291	2.80(3)	0.0001
	Acetone	215.10 ± 0.065 (205.64-224.70)	331.70 ± 0.065 (309.98-361.95)	Y = 6.8134 X ± 10.8933	3.22(3)	0.0001

LC_{50}=Median lethal concentration, LC_{90}= 90% lethal concentration, LCL=Lower confidence limit, UCL=Upper confidence limit df = degree of freedom * The difference in LC_{50} is significant based on the non overlapping of 95% Fiducial limit (P<0.05)

Table 2: Ovicidal activity of different solvent extracts of *Dalbergia oliveri* leaf against *Culex quinquefasciatus*

Treatment	% Egg Hatchability at different Concentrations (Mean±SE)						
Solvents	20 ppm	40 ppm	60 ppm	80 ppm	100 ppm	LC_{50}±SE (LCL-UCL)	P -value
Petroleum ether	57.75±1.25	30.75±0.85	16.50±2.02	7.00±1.58	0.00±0.00	24.98 ±0.28 (21.15-28.42)	0.0001
Ethyl acetate	68.75±4.04	47.50±5.63	24.25±1.43	17.50±2.21	4.25±1.54	33.16 ±0.26 (28.84-37.15)	0.0001
Chloroform	83.50±4.73	66.75±5.29	51.25±8.45	25.50±5.26	11.75±4.44	50.310 ±0.53 (33.83-69.36)	0.0001
Methanol	88.75±6.63	70.00±8.72	52.25±7.11	30.00±7.35	8.75±3.25	53.47 ±0.59 (37.61-72.41)	0.0001
Acetone	90.00±6.33	70.75±8.39	55.50±10.74	37.50±9.75	9.00±3.93	56.68 ±0.67 (37.31-84.23)	0.0001
Control	100.0 ± 00						0.0001

Table 2.1. Ovicidal activity of different solvent extracts of *Heracleum rigens* seed against *Culex quinquefasciatus*

Treatment	% Egg Hatchability at different Concentrations (Mean±SE)						
Solvents	25 ppm	50ppm	75 ppm	100 ppm	125ppm	LC_{50}±SE (LCL-UCL)	P -value
Petroleum ether	56.75±2.78	42.75±1.18	29.25±3.06	7.00±4.77	0.00±0.00	34.83 ±0.75 (0.70-57.41)	0.0001
Ethyl acetate	74.50±5.33	51.75±6.79	22.25±2.75	11.00±1.87	4.00±2.62	43.99 ±0.28 (39.30-48.42)	0.0001
Chloroform	77.25±4.02	53.50±2.10	32.25±4.90	15.75±5.40	3.75±2.83	48.11 ±0.44 (33.55-61.10)	0.0001
Methanol	81.75±5.34	58.75±4.49	36.25±9.17	18.00±6.25	4.50±3.06	52.74 ±0.47 (37.99-66.63)	0.0001
Acetone	89.75±3.98	65.75±8.55	44.50±11.89	27.00±10.15	6.50±3.57	62.55 ±0.49 (48.02-77.84)	0.0001
Control	100.0 ± 00						0.0001

Mean±standard error (SE) of four replicates. Means are separated by Tukey's test of multiple comparison, one-way analysis of variance (ANOVA). ppm = parts per million. P<0.05, level of significance.

RESULTS

The results of the larvicidal activity of a different solvent extract of *D. oliveri* and *H. rigens* against the larvae of *Cx. quinquefasciatus* are presented in table 1 and Figure 1 and 2. The larvicidal activity in terms of LC_{50} by petroleum ether, ethyl acetate, chloroform, methanol and acetone extracts of *D. oliveri* leaves are 36.28, 94.56, 104.13, 156.73, 169.69ppm respectively. Likewise, theLC_{50} values of petroleum ether, ethyl acetate, chloroform, methanol and acetone extracts of *H. rigens*are 69.25, 92.61, 115.08, 165.94, 215.10ppm respectively. The highest larvicidal activity was observed in petroleum ether extract of *D. oliveri* with LC_{50} and LC_{90} values of 36.28ppm and 60.61ppm respectively. The larvicidal activity was found to be significantly different between the extracts (P<0.05).

The extracts of *D. oliveri* leaf and *H. rigens*seed were tested for ovicidal activity at different concentrations. The percentage of egg hatchability of the vector in various extracts is presented in table 2 and 2.1. The petroleum ether extracts of both *D. oliveri* and *H. rigens* exerted 100% mortality at 100ppm and 125ppm respectively. The LC_{50} value for *D. oliveri*in the experiment was 24.98ppm as against 34.83ppm in *H. rigens*. In all treatment, the ovicidal activity was concentration dependent. Results of oviposition deterrent activity with different solvent extracts of *D. oliveri* and *H. rigens* against *Cx. quinquefasciatus* is given in Table 3 and 3.1. Here too petroleum ether extract significantly deterred oviposition by *Cx. Quinquefasciatus* gravid female at all the concentration tested as they preferred to lay eggs in a control medium compared to the treated solution (p<0.05). Strong deterrent (100%) was found at a concentration of 50ppm for *D. oliveri* extract and 125ppm for *H. rigens* extract.

Table 3. Oviposition deterrent activity of different solvent extracts of *Dalbergia oliveri* leaf against *Culex quinquefasciatus*

Solvents	10ppm			20ppm			30ppm			40ppm			50ppm			Control			LC_{50}±SE	p-value
	Mean±SE	ER%	OAI	Mean±SE	ER%	OAI	Mean±SE	ER%	OAI	Mean±SE	ER%	OAI	Mean±SE	ER%	OAI	Mean±SE	ER%	OAI	(LCL-UCL)	
Petroleum ether	702.3±2.74	36.48	-0.22	411.33±1.28	62.82	-0.52	319.33±9.2	71.13	-0.55	101.33±2.6	90.84	-0.83	0.0±0.0	100	-1.00	1106.33±3.1	00	00	14.62±0.62 (4.73-21.45)	0.0001
Ethyl acetate	661.33±2.73	18.48	-1.10	442.00±1.82	45.52	-0.29	368.33±1.51	54.60	-0.37	221.33±9.1	72.72	-0.57	177.66±3.03	98.10	-0.64	811.33±5.87	00	00	23.73±0.25 (20.97-26.59)	0.0001
Chloroform	712±2.85	18.03	-0.09	535.00±2.12	38.41	-0.23	375.00±1.36	56.83	-0.39	227.33±8.1	73.82	-0.58	10.66±1.06	98.77	-0.97	868.60±5.32	00	00	22.50±0.75 (10.34	0.0001
Methanol	758.33±3.01	18.60	-0.01	534.00±2.56	42.61	-0.27	436.00±2.07	53.20	-0.36	266.33±1.5	71.41	-0.55	53.66±1.13	94.24	-0.73	931.66±3.12	00	00	22.85±0.59 (12.66-33.32)	0.0001
Acetone	788.66±3.37	16.69	-0.09	404.40±1.6	57.32	-0.40	317.00±1.39	66.47	-0.49	111.66±4.53	88.20	-0.78	35.33±1.46	93.76	-0.88	946.66±2.98	00	00	19.12±0.28 (17.24-20.93)	0.0001

Mean±standard error (SE) of four replicates. Means are separated by Tukey's test of multiple comparison, one-way analysis of variance (ANOVA). ppm = parts per million.

Table 3.1. Oviposition deterrent activity of different solvent extracts of *Heracleum rigens* seedagainst *Culexquinquefasciatus*

Solvents	25ppm			50ppm			75ppm			100ppm			125ppm			Control			LC_{50}±SE	p-value
	Mean±SE	ER%	OAI	Mean±SE	ER%	OAI	Mean±SE	ER%	OAI	Mean±SE	ER%	OAI	Mean±SE	ER%	OAI	Mean±SE	ER%	OAI	(LCL-UCL)	
Petroleum ether	299.00±1.63	26.17	-0.15	166.00±0.17	59.01	-0.41	59.00±8.12	85.43	-0.74	11.00±1.50	97.28	-0.94	00.00	100.00	-1.00	405.00±2.13	00	00	39.03±0.61 (18.66-54.90)	0.0001
Ethyl acetate	305.00±1.64	17.11	-0.09	184.00±0.71	50.00	-0.33	136.00±0.40	63.04	-0.46	77.00±8.00	79.07	-0.65	27.00±2.02	92.66	-0.86	368.00±1.25	00	00	51.96±0.27 (46.74-57.05)	0.0001
Chloroform	292.00±1.70	27.90	-0.16	196.00±1.03	51.60	-0.34	150.00±0.25	62.96	-0.45	92.00±7.06	77.28	-0.60	43.00±1.17	89.38	-0.80	405.00±4.87	00	00	47.05±0.75 (40.70-53.02)	0.0001
Methanol	312.00±2.02	24.27	-0.13	208.00±3.67	49.51	-0.32	172.00±3.18	58.25	-0.41	106.00±2.06	74.27	-0.59	63.00±2.24	84.70	-0.73	412.00±6.98	00	00	50.61±0.27 (44.31-56.62)	0.0001
Acetone	330.00±2.48	34.26	-0.20	244.00±2.78	51.39	-0.34	198.00±2.40	60.55	-0.43	120.00±4.64	76.09	-0.61	77.00±2.47	84.66	-0.73	502.00±2.76	00	00	44.78±0.24 (37.02-51.84)	0.0001

Mean±standard error (SE) of four replicates. Means are separated by Tukey's test of multiple comparison, one-way analysis of variance (ANOVA). ppm = parts per million.

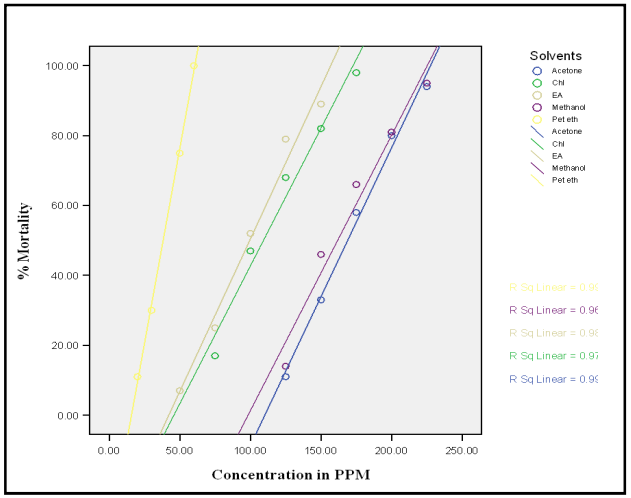

Fig. 1. Dosage mortality response of different solvent extracts of *Dalbergia oliveri* leaf against larvae of *Culex quinquefasciatus*

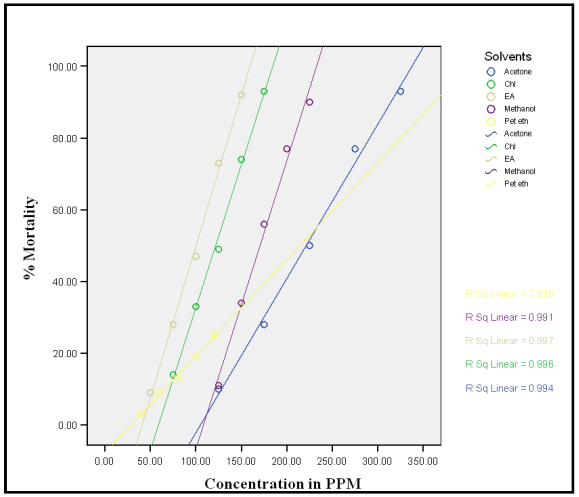

Fig. 2. Dosage mortality response of different solvent extracts of *Heracleum rigens*seed against larvae of *Culex quinquefasciatus.*

The LC_{50} value of ER% of *D. oliveri* and *H.rigens* against *Cx. Quinquefasciatus* found to be 14.62ppm and 39.03ppm respectively. All the OAI values recorded for both species exhibit negative values that from -0.01 to -1.00, which is indicates strong repellency towards test solution. The ER% observed among various extracts indicated significant ($p<0.05$) difference when compared to control.

DISCUSSION

After facing several problems due to indiscriminate application of synthetic insecticides, for a long time, re-focus on phytochemicals that are easily biodegradable and have no ill-effects on non-target organisms was appreciated. So as a part of the search for new ecofriendly compounds from local plant species, an effort is made here to isolate and identify a few compounds. At present phytochemicals makeup to one percent of the world's pesticide market. The efficacy of phytochemicals against mosquito larvae can vary significantly depending on plant species, plant parts used, the age of plant parts (young, mature or senescent), the solvent used during extraction as well as upon the available vector species (Bagavan *et al.,* 2008). The existence of variations in the level of effectiveness of phytochemical compounds on target mosquito species depends on plant parts from which these were extracted, responses in species and their developmental stages against the specified extract, solvent of extraction, geographical origin of the plant, photosensitivity of some of the compounds in the extract, effect on growth and reproduction (Sukumar *et al.,* 1991). The screening of locally available medicinal plants for mosquito control would generate local employment, reduce dependence on expensive imported products, and stimulate local efforts to enhance public health. In this regard, an earlier experiment carried out by Prathibha *et al* (2014) in our lab employing *Eugenia jambolana, Solidago canadensis, Euodia ridley,* and *Spilanthes mauritiana* plant species as larvicidal, ovicidal and oviposition deterrent activity yielded a good result and thereby the methodology was standardized.

The present study further throws light on the probable insecticidal property of solvent extracts of *D.oliveri* leaves and seed extracts of *H.rigens* against the different stages of *Cx. Quinquefasciatus* development. The results indicate that among various solvent extracts obtained, petroleum ether extract has been found to possess significant larvicidal, ovicidal and oviposition deterrent efficacy in both the plant species under study ($p<0.05$). Between the two plants, *D. oliveri* has exhibited more efficacy with larvicidal, ovicidal and oviposition deterrent activity against *Cx. Quinquefasciatus* (Table 1, 2 and 3). In line with the present data, several species belonging to Genus *Dalbergia* have been shown to possess insecticidal properties. *D. soxatilis* possess insecticidal property against *Aedes* mosquito species (Okwute *et al.,* 2009). The previous research results on Apiaceae family revealed significant mosquitocidal efficacy (Navaneet *et al.,* 2011). Pavela (2008) has reported larvicidal activity of *Ammivisnaga* seed extracts against *Cx. quinquefasciatus and An.stephensi* mosquito. *Anethum graveolons* too showed good larvicidal activity against *Cx.quinquefasciatus and Ae.aegypti* (Amer and Mehlhorn, 2006). *Heracleum spondylium* too possesses larvicidal activity against *Culexpipiens* (Evergetis *et al.,* 2009). This result is also comparable to earlier reports of Vahitha *et al.* (2002) who observed the larvicidal activity of leaf extracts of *Pavonia zeylanica* and *Acacia ferruginea* on *Cx.quinquefasciatus.* The two plant species, *D.oliveri* and *H. rigens*tested by the author in the present investigation at Mysuru have exhibited promising ovicidal activity at 100ppm and 125ppm respectively in *Cx. quinquefasciatus* respectively (Table 2 and 2.1). A similar ovicidal effect of the seed extract of *A. canescens* was reported earlier against *Cx. quinquefasciatus* (Oudo *et al.,* 1998). Govindarajan *et al.* (2011) have also demonstrated that the crude extract of *Eugoa coronaria* and *Caesalpinia pulcherrima* exerted ovicidal efficacy at different concentrations against *Cx. Quinquefasciatus* and *Ae. Aegypti* at Tamil Nadu. *Trachspermumammi* seed extracts too exhibited ovicidal activity against *An.stephensi* (Pandey, 2009). Differences in susceptibility to ovicides may be due to differential rates of uptake, penetration through the chorine, and conversion to the active inhibitor, detoxification, and failure of the toxicants to reach the target.

The efficacy to act on the embryo inside the egg shell depends on the efficient penetration of the insecticides, which in turn is influenced by the exposure period (Grosscurt, 1977). The same effect may be true for the present study as well as the current study clearly indicate that the ovicidal activity of the plant extract against egg raft may depend upon three key factors viz., a dose of the plant extract, the age of the egg raft and period of exposure. This observation is also in agreement with the work of Prathibha*et al.* (2014) on the same vector species with *Eugenia jambolana* and three more plant species at Mysuru. Oviposition is one of the most important eventsin the life cycle of mosquitoes. By reducing the oviposition the mosquito life cycle can be disrupted and thereby population growth reduced (Xue *et al.,* 2001). Mosquitoes are known to select or reject their specific oviposition sites by sensing chemical signals that are detected by sensory receptors on the antennae and legs. The present data indicate that petroleum ether extract of both the plants exhibited significant oviposition deterrent effect on the vector mosquito ($p<0.05$). In line with this finding *Trachyspermumammi* seed extracts was found to exhibit oviposition deterrent activity against *An.stephensi* (Pandey, 2009). Further, seed extracts of *Pimpinellaanisum* too showed ovicidal, oviposition deterrent and repellent activity against *Aedes, Anopheles* and *Culex* mosquito (Prajapati *et al.,* 20056). The strong odour produced by concentrations of leaf extract in the present experiment might have produced repellency thereby preventing oviposition.

Conclusion

Thus, the present findings highlight the importance of *D. oliveri* and *H.rigens* which exhibited larvicidal, ovicidal, and oviposition deterrent activity against the vector mosquito under study. These results could encourage the search for new active ecofriendly compounds in addition to already existing plant products with insecticidal property. These plant extracts may contribute greatly to save the environment and to an overall reduction in the population density of the vector,*Cx. quinquefasciatus*. Further studies on the isolation and characterization of the bioactive molecule from these plant species are in the pipeline.

Abbreviations

WHO – World Health Organisation
OAI - Oviposition Activity Index

UCL - Upper Confidence Limit
LCL - Lower Confidence Limit
ANOVA - One-way analysis of variance
SPSS - Statistical Package of Social Sciences

Acknowledgment: The authors are grateful to the Chairperson, Department of Studies in Zoology, University of Mysore, Mysuru for providing necessary facilities.

Conflict of interest: None

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