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Larvicidal activity and leaf essential oil composition of three species of genus *Atalantia* from south India

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Abstract
Mosquito is a vector of several life threatening diseases affecting humans. The use of synthetic insecticides in the vector control is not advisable due to lack of novel insecticides, high cost, concern for environmental sustainability, harmful effect on human health and increasing insecticide resistance on a global scale. A comparative account on the larvicidal efficiency of the plants of Genus *Atalantia* was not reported so far. Therefore in the present work the larvicidal activity of the leaf essential oils of the three selected *Atalantia* species were tested. Also the chemical composition of the essential oils was analyzed by GC/MS. Essential oil was isolated from the fresh leaves of the three species using Clevenger type apparatus. The larvicidal activity of the leaf essential oils were tested according to the WHO procedure (WHO, 1981). In the comparative analysis the leaf essential oil of *A. racemosa* showed maximum activity against the larvae of three selected mosquito species namely *Aedes aegypti*, *Anopheles stephensi* and *Culex quinquefasciatus*.

Keywords: *Atalantia*, Essential oil, Larvicidal activity, GC/MS

1. Introduction

Mosquito is the vector of life threatening diseases affecting humans such as Malaria, Yellow fever, Dengue, Chikungunya, Filariasis, Encephalitis, West Nile virus infection etc. These diseases are prevalent in more than 100 countries in tropical and subtropical regions of the world. To prevent the epidemics caused by mosquito and to improve quality of environment and public health, mosquito control is essential. The use of synthetic insecticides is not advisable due to lack of novel insecticides, high cost, concern for environmental sustainability, harmful effect on human health and other non-target populations, their non biodegradable nature, higher rate of biological magnification and increasing insecticide resistance on a global scale. Unlike chemical insecticides which are based on a single active ingredient, plant derived insecticides consist of a combination of chemical compounds which act concertedly on both behavioral and physiological processes. Thus there is very little chance of insects developing resistance to plant based pesticides. Identifying bio-insecticides that are efficient, as well as being suitable and adaptive to ecological conditions, is imperative for continued effective vector control management [1]. The control of mosquito at the immature stage is necessary and efficient in integrated mosquito management because during the immature stages, mosquitoes are immobile [2]. Therefore identifying plant extracts with larvicidal potential is one of the effective ways to prevent those vector borne diseases.

Essential oils are concentrated hydrophobic liquids isolated from plants which are rich in aromatic compounds. The roles of essential oils in plants are attraction of pollinating insects by attractive volatile aromas, reduction of competition from other plant species (allelopathy) by chemical inhibition of seed germination and establishment, and protection against insects by an anesthetic effect, against infectious micro flora by fungicidal and bactericidal properties, and against browsing animals by adverse taste and effects on the nervous system. Essential oils from several plant species have been extensively tested to assess their larvicidal potential and proved to be very effective [1, 3]. In an earlier work the methanolic extract of leaves of *Atalantia monophylla* was investigated for larvicidal and pupicidal activity against immature stages of three mosquito species, *Culex quinquefasciatus*, *Anopheles stephensi* and *Aedes aegypti*. Larvae of *Cx. quinquefasciatus* and pupae of *An. stephensi* were found more susceptible, with LC_{50} values of 0.14mg/l and 0.05 mg/l respectively. Also insect growth regulating activity was tested and more pronounced results were obtained against *Ae. aegypti*, with EI_{50} value of 0.002mg/l. The results indicate that the mosquitocidal effects were comparable to Neem extract and certain synthetic chemical larvicides like fenthion and methoprene [4].

Three plants belonging to the genus *Atalantia* (Family: Rutaceae) namely *Atalantia monophylla* (Roxb.) DC., *A. racemosa* Wight. and *A. wightii* Tanaka were selected for the present study. Both *A. monophylla* and *A. racemosa* are widely distributed in south India, while *A. wightii* is endemic to shola forests of Western Ghats. A comparative account on the larvicidal efficiency of the plants of Genus *Atalantia* was not reported so far. Therefore in the present work the larvicidal activity of the leaf essential oils of the three selected *Atalantia* species was tested.

2. Materials and methods

2.1. Isolation of essential oil

The essential oils were isolated from fresh leaf samples collected from different places in south India. *A. monophylla* leaves were collected from Nagamalai hills of Madurai district, Tamilnadu. The leaves of *A. racemosa* and *A. wightii* were collected from Meghamalai hills, Theni, Tamilnadu and the Shola forests near Vaguvarai estate, Munnar, Kerala respectively. The plants were collected during the month of March 2011. The leaves were first washed with tap water and then dried under fan for 10 min. They were then weighed and chopped to small pieces, after that hydrodistilled in a Clevenger type apparatus for 3 hr in 200 ml water at 100º C. The essential oil was carefully collected in a screw cap bottle and dried over anhydrous Sodium sulphate. Essential oil was stored at -20 °C for further analysis.

2.2. GC/MS Analysis of essential oil

A Shimadzu QP-2010 plus with thermal desorption system TD 20 was used to obtain the chromatograms. The name and specification of the column used is AB-Innowax (60 m X 0.25 mm X film thickness-0.25 µm). The temperature was programmed from 50°C with 5 minute initial hold to 280°C at 4° C/min and a final hold for 5 min at 280°C. The injector and detector temperature were set at 220°C and 240°C respectively and the split ratio was 1/60. Helium was used as the carrier gas and the ionizing voltage used is 70 eV. The components were identified based on the library search carried out using NIST and WILEY library.

2.3. Larvicidal activity

The larvicidal activity of the leaf essential oils was tested according to the WHO procedure [5]. Larvicidal activity was tested against three mosquito vectors namely *Aedes aegypti*, *Anopheles stephensi* and *Culex quinquefasciatus*. The larvae were obtained from Centre for research in Medical Entomology, Madurai. The essential was dissolved in ethanol (99.8%) to make the stock solution of 10000ppm (10µl/1ml). This stock solution was further diluted in water to make different concentrations. The oil- ethanol- water solution was stirred for 30 sec with glass rod. After above 15 min, 25 larvae taken on a strainer with fine mesh were transferred gently to the test medium by tapping. For each dose, 3 replicates were maintained. Food (dry yeast) was sprinkled in each container. After 24 h, mortality count was observed. Simultaneous control sets (with 1ml ethanol in 249 ml water) were also setup. The average larval mortality data were subjected to probit analysis for calculating LC_{50} values using Biostat 2009 5.8.3.0 software.

3. Results and discussion

The leaf essential oil of *A. monophylla* exhibited larvicidal activity at all the tested concentrations against the three selected mosquito vectors *Ae. aegypti, Cu. quinquefasciatus* and *An. Stephensi.* The essential oil of *A. monophylla* showed better inhibition against *An. stephensi* than the other two vectors. At 200ppm concentration the essential oil showed 100% mortality against mosquito larvae of all the three species (Table 1). The LC_{50} values were 93.2ppm, 97.09ppm and 97.13ppm against *Ae. aegypti, An. stephensii* and *Cu. quinquefasciatus* respectively (Table 4). Similar trend was also shown for LC_{90} values also. In an earlier work the methanol extract of *A. monophylla* shows similar results against the three selected mosquito vectors selected in this study. In that study larvae of *C. quinquefasciatus* and pupae of *A. stephensi* were found more susceptible, with LC_{50} values of 0.14 mg/l and 0.05 mg/l, respectively. Insect growth regulating activity of this extract was more pronounced against *A. aegypti,* with EI_{50} value 0.002 mg/l. The extract was found safe to aquatic mosquito predators *Gambusia affinis, Poecilia reticulata* and *Diplonychus indicus* with the respective LC_{50} values of 23.4, 21.3, and 5.7 mg/l. In another report Hexane, chloroform and ethyl acetate crude extracts of *Atalantia monophylla* leaf were studied for ovicidal activity against *Helicoverpa armigera*. The least LC50 value of 2.60% was observed in hexane extract. The chloroform and ethyl acetate extracts manifested ovicidal activity of 47.49 and 43.36% respectively [6]. The results obtained in this study and the previous reports prove that the essential oil of *A. monophylla* is a very good larvicidal agent against the common mosquito vectors.

Table 1: Larvicidal activity of Genus *Atalantia* against three selected mosquito species

Plant Name	Conc. (ppm)	*Aedes aegypti*		*Anopheles stephensi*		*Culex quinquefasciatus*	
		Mortality (%)		Mortality (%)		Mortality (%)	
		After 24h	After 48h	After 24h	After 48h	After 24h	After 48h
A. monophylla	50	16.67±6.9	25±8.7	60±2.9	63.33±4.4	41.67±6.0	43.33±4.4
	75	38.33±12.0	41.67±8.8	83.33±4.4	85±5.8	70.0±2.9	70.0±2.9
	100	58.35±1.7	70±10.0	100	100	71.67±8.8	75±10.4
	150	95±5.0	95±5.0	100	100	91.67±1.6	95±2.9
A. racemosa	50	33.33±1.7	35	31.67±1.7	31.67±1.7	23.33±4.4	31.67±4.4
	75	38.33±1.7	38.3±1.7	55±5.8	56.67±4.4	40.0±2.9	40±2.9
	100	61.67±3.4	65±5.8	75±5.0	93.3±3.3	61.67±4.5	71.67±14.3
	150	78.33±1.7	81.66±1.7	100	100	100.0	100.0
A.wightii	50	11.67±1.7	11.67±1.7	46.67±1.7	46.67±1.7	30±2.8	31.6±4.4
	75	20±0	23.33±3.3	53.33±1.7	56.67±4.4	43.33±1.7	45±2.9
	100	41.67±3.4	45±5.8	63.33±3.3	65±5.6	56.67±4.5	60±7.7
	150	46.66±6.0	48.33±7.3	78.33±4.4	81.67±1.7	78.33±1.7	78.33±1.6

Larvicidal activity of *A. racemosa* essential oil also showed similar trends that of the *A. monophylla* essential oil. 100% mortality was observed for both *C. quinquefasciatus* and *A. stephensi* at 100ppm concentration while for *A. aegypti* it was observed at 200ppm (Table 2). The LC_{50} values were 50.11 ppm, 72.39 ppm and 154.65 ppm against *A.aegypti*, *A. stephensii*. and *C. quinquefasciatus* respectively (Table 4). Lutharia ***et al.***, 1989 reported several insect antifeedants from the aerial parts of this plant. In terms of activity against the larvae of selected mosquito vectors the essential oil of *A. racemosa* is better than *A. monophylla*.

Table 2: LC_{50} and LC_{90} values of essential oils of the three species against the selected mosquito larvae

Plant Name	*Aedes aegypti*		*Anopheles stephensi*		*Culex quinquefasciatus*	
	LC_{50} ppm	LC_{90} ppm	LC_{50} ppm	LC_{90} ppm	LC_{50} ppm	LC_{90} ppm
A. monophylla	93.2	146.12	50.11	107.69	80.8	146.37
A. racemosa	97.09	175.77	72.39	130.09	86.15	140.64
A. wightii	97.13	177.03	154.65	261.6	122.1	231.85

Cent percentage mortality at 200ppm was observed against the larvae of *A. stephensi* only in the case of essential of *A. wightii*. The LC_{50} values were 97.13 ppm, 154.65 ppm and 122.1 ppm against *A. aegypti, A. stephensii*. and *C. quinquefasciatus* respectively (Table 3-4). In comparison with the other two species, essential oil of *A. wightii* was the least effective against the larvae of all the three tested mosquito species. Still based on the obtained results the essential oil of this species is a very effective larvicidal agent.

The extract percentages of the obtained essential oils isolated were found to be 0.2%, 0.17% and 0.31% for *A. monophylla*, *A. racemosa* and *A. wightii* respectively. Twenty nine compounds were identified from the essential oils of *A. monophylla* (Fig. 1, Table 3). The major compounds identified were α-Asarone (28.82%), Sabinene (13.19%), Eugenol methyl ether (12.71%), 1,2-Dimethoxy-4-(2-methoxyethenyl)benzene (11.63%) and β-Pinene (5.3%). A total of 65 compounds were identified from the essential oil of *A. racemosa* (Fig 1, Table 3). The major components identified were T-Cadinol (11.08%), Caryophyllene oxide (9.78%), β- Caryophyllene (9.20%), Spathulenol (7.21%), β-Phellandrene (5.67%) and Decanal (4.01%). The extract percentage of the essential oil was highest in *A. wightii* compared to the other two. The chromatogram obtained was analysed and a total of 64 compounds were identified. The major compounds identified were β- Caryophyllene (16.37%), D-Limonene (12.15%), Decanal (10.49%), β- Myrcene (7.67%), Tetradecanal (6.99%), Caryophyllene oxide (6.29%) and Hexadecylene oxide (5.87%) (Fig. 1, Table 3). Bicyclogermacrene, Caryophyllene oxide, Dodecanal, T-Cadinol, α- Cadinol, α- Caryophyllene, β- Caryophyllene, α-Pinene, β- Myrcene, β-Phellandrene and β- Elemene were found in all the three species. Terpenes especially the mono and Sesquiterpenes were the major components in all the three species. Previous studies have proved that the terpenoid compounds were effective as repellent, larvicidal, pupicidal or adulticidal against different species of Mosquito [7]. The study concludes that all the three species could be used as an environmental friendly pesticide. Further studies are required to reveal the mode of action of the individual constituents as well as their effect on non target organisms such as small fishes that feed on the larvae before it can be used commercially.

Table 3: Chemical composition of the essential oils of three *Atalantia* species

Compound name	Molecular formulae	*A. Monophylla*		*A. Racemosa*		*A. Wightii*	
		Retention time	Peak area (%)	Retention time	Peak area (%)	Retention time	Peak area (%)
(2-Methylbutyl)cyclopentane	$C_{10}H_{20}$	-	-	24.42	0.34	24.43	0.5
(E)-4,8-Dimethyl-1,3,7-nonatriene	$C_{11}H_{18}$	-	-	12.06	0.21	-	-
1- Undecanol	$C_{11}H_{24}O$	-	-	28.09	0.37	28.10	0.23
1,2-Dimethoxy-4-(2-methoxyethenyl)benzene	$C_{11}H_{14}O_3$	31.91	11.63	-	-	-	-
10,12-Pentacosadiynoic acid	$C_{25}H_{42}O_2$	-	-	43.88	1.32	-	-
10-Methoxy-nb-alpha-methylcorynantheol	$C_{21}H_{29}N_2O_2$	-	-	43.37	0.27	-	-
14-Hydroxy-α-humulene	$C_{15}H_{24}O$	-	-	-	-	41.79	0.17
1-Decanol	$C_{10}H_{22}O$	-	-	25.30	0.61	25.32	2.63
1-Decyne	$C_{10}H_{18}$	-	-	19.53	0.1	-	-
1-Dodecanol	$C_{12}H_{26}O$	-	-	30.84	0.66	30.85	0.81
1-Octanol	$C_8H_{18}O$	-	-	19.37	0.1	-	-
2-Nonen-1-ol	$C_9H_{18}O$	-	-	13.66	0.64	13.67	0.14
3,5,5-Trimethylhexene-1	C_9H_{18}	-	-	16.80	0.1	-	-
4-(2,4,6-Trimethoxyphenyl)-2-butanol	$C_{13}H_{18}O_4$	28.91	1.96	-	-	-	-
4-Terpineol	$C_{10}H_{18}O$	17.64	3.62	-	-	-	-
5,5-Dimethyl-4-[3-methyl-1,3-butadienyl]-1-oxaspiro[2.5]octane	$C_{14}H_{22}O$	-	-	41.79	0.35	43.88	0.36
6-Methyl-1-octanol	$C_9H_{20}O$	-	-	21.48	0.5	21.49	2.04
8-Dodecen-1-ol	$C_{12}H_{24}O$	-	-	-	-	32.02	0.56
8-Methyl-2-decene	$C_{11}H_{22}$	-	-	-	-	27.23	0.55
Adenosine	$C_{10}H_{13}N_5O_4$	-	-	46.41	0.23	-	-
Alloaromadendrene	$C_{15}H_{24}$	-	-	22.32	0.5	42.12	1.76
Alloaromadendrene oxide-(1)	$C_{15}H_{24}O$	-	-	42.11	3.82	-	-

Bicycloelemene	$C_{15}H_{24}$	-	-	-	-	17.35	0.12
Bicyclogermacrene	$C_{15}H_{24}$	28.14	2.67	24.82	0.51	24.86	2.06
Butanoic acid, 2-methyl-, octyl ester	$C_{13}H_{26}O_2$	-	-	21.59	0.51	-	-
Caryophyllene oxide	$C_{15}H_{24}O$	30.81	0.52	31.76	9.68	31.79	6.39
Cedrene	$C_{15}H_{24}$	-	-	-	-	19.09	0.13
cis- β- Ocimene	C_8H_{12}	-	-	10.57	0.16	-	-
cis-3-Hexanol	$C_6H_{14}O$	-	-	-	-	14.22	0.21
cis-Carane	$C_{10}H_{18}$	-	-	-	-	36.71	0.3
cis-Limonene oxide	$C_{10}H_{16}O$	-	-	-	-	16.31	0.06
cis-Nerolidol	$C_{15}H_{26}O$	-	-	33.11	0.64	15.42	0.08
cis-Z-α-Bisabolene epoxide	$C_{15}H_{24}O$	-	-	-	-	32.24	0.27
Cubenol	$C_{15}H_{26}O$	-	-	34.00	0.64	34.01	0.17
Cyclohept -4-enol	$C_7H_{12}O$	-	-	-	-	15.13	0.06
Cymene	$C_{10}H_{14}$	-	-	11.20	1.04	11.21	0.1
Decanal	$C_{10}H_{20}O$	-	-	17.81	4.01	17.86	10.49
D-Limonene	$C_{10}H_{16}$	-	-	-	-	9.43	12.15
Dodecanal	$C_{12}H_{24}O$	17.29	2.68	24.01	1.86	16.40	0.35
Elemol	$C_{15}H_{26}O$	-	-	34.62	0.64	34.63	0.39
Ent-Spathulenol	$C_{15}H_{24}O$	-	-	37.24	1.14	38.62	0.32
Epiglobulol	$C_{15}H_{26}O$	-	-	-	-	34.91	0.09
Eugenol-methyl ether	$C_{11}H_{14}O_2$	25.45	12.71	-	-	-	-
Germacrene B	$C_{15}H_{24}$	-	-	20.27	0.19	-	-
Germacrene D	$C_{15}H_{24}$	27.71	4.4	24.14	0.75	-	-
Geyrene	$C_{12}H_{18}$	-	-	-	-	12.74	0.06
Globulol	$C_{15}H_{26}O$	30.99	0.21	-	-	43.73	0.12
Hex-3-en-1-ol	$C_6H_{12}O$	-	-	14.21	0.07	-	-
Hexadecanal	$C_{16}H_{32}O$	-	-	16.39	1.92	-	-
Hexadecylene oxide	$C_{16}H_{32}O$	-	-	19.96	3.13	19.99	5.87
Humulene oxide	$C_{14}H_{22}O$	-	-	33.52	1.45	33.54	0.42
Iso spathulenol	$C_{15}H_{24}O$	-	-	40.14	0.31	-	-
Isocaryophyllene	$C_{15}H_{24}$	-	-	-	-	33.65	0.4
Ledene oxide-(II)	$C_{15}H_{24}O$	-	-	-	-	37.26	0.71
Ledol	$C_{15}H_{26}O$	-	-	40.95	0.46	33.09	0.14
Limonene epoxide	$C_{10}H_{16}O$	-	-	43.72	0.32	-	-
Linalool	$C_{10}H_{18}O$	-	-	19.07	0.42	-	-
Linalyl iso-valerate	$C_{15}H_{26}O_2$	-	-	29.61	0.47	-	-
Muurolene	$C_{15}H_{24}$	-	-	25.53	0.3	-	-
n-Capric acid	$C_{10}H_{20}O_2$	-	-	-	-	41.65	0.13
Nonanal	$C_9H_{18}O$	-	-	14.66	0.05	14.66	0.08
Nonanol	$C_9H_{20}O$	-	-	-	-	22.39	0.64
Octyl isovalerate	$C_{13}H_{26}O_2$	-	-	22.10	1.35	-	-
Oleic acid	$C_{18}H_{34}O_2$	-	-	41.63	0.56	43.38	0.09
Oxirene	C_2H_2O	21.27	0.46	-	-	-	-
Phytol	$C_{20}H_{40}O$	-	-	49.36	2.24	49.35	0.23
Pinadiene	$C_{10}H_{14}$	10.78	0.36	-	-		-
p-Mentha-1(7),8(10)-dien-9-ol	$C_{10}H_{16}O$	-	-	-	-	46.33	0.46
Sabinene	$C_{10}H_{16}$	9.64	13.19	-	-	7.68	0.09
Selina-6-en-4-ol	$C_{15}H_{26}O$	-	-	-	-	30.29	0.14
Spathulenol	$C_{15}H_{24}O$	-	-	36.37	7.21	36.41	4.18
T-cadinol	$C_{15}H_{26}O$	32.57	0.3	38.29	11.08	38.30	1.96
Tetracyclo[6.3.2.0(2,5).0(1,8)]tridecan-9-ol, 4,4-dimethyl-	$C_{15}H_{24}O$	-	-	-	-	41.98	0.45
Tetradecanal	$C_{14}H_{28}O$	-	-	-	-	24.06	6.99
Trans- Longipinocarveol	$C_{15}H_{24}O$	-	-	-	--	43.01	0.08
Tridecanal	$C_{13}H_{26}O$	-	-	-	-	29.79	0.06
Undec-4-enal	$C_{11}H_{20}O$	-	-	25.03	0.58	-	-
Viridiflorene	$C_{15}H_{24}$	-	-	42.66	0.44	-	-
Z-7-Tetradecenal	$C_{14}H_{26}O$	-	-	-	-	25.10	1.86
Z-9-Hexadecenal	$C_{16}H_{30}O$	-	-	-	-	30.75	0.1
α -Bergamotene	$C_{15}H_{24}$	26.17	0.17	20.44	0.89	-	-
α -Caryophyllene	$C_{15}H_{24}$	26.86	0.53	23.02	2.24	23.06	3.06
α- Ionone	$C_{13}H_{20}O$	-	-	-	-	27.99	0.07
α- Pinene	$C_{10}H_{16}$	8.02	0.56	6.08	0.23	6.08	0.05
α -Terpinene	$C_{10}H_{16}$	11.27	0.83	-	-	-	-
α -Terpinolen	$C_{10}H_{16}$	-	-	11.51	0.03	-	-
α-Asarone	$C_{12}H_{16}O_3$	30.65	28.82	-	-	-	-

α-Bulnesene	$C_{15}H_{26}$	-	-	46.33	1.02	-	-
α-cadinol	$C_{15}H_{26}O$	32.96	0.2	40.33	2.97	38.87	0.09
α-Curcumine	$C_{15}H_{22}$	-	-	25.84	1.10	-	-
α-Guaiene	$C_{15}H_{24}$	27.00	0.2	-	-	-	-
α-Limonene	$C_{10}H_{16}$	-	-	9.36	0.97	-	-
α-Terpinolene	$C_{10}H_{16}$	13.98	0.25	-	-	-	-
β- Asarone	$C_{12}H_{16}O_3$	29.88	1.34	-	-	-	-
β -Myrcene	$C_{10}H_{16}$	10.28	0.59	8.42	1.45	8.46	7.67
β- Phellandrene	$C_{10}H_{16}$	11.80	1.13	9.63	5.67	9.65	1.73
β- Pinene	$C_{10}H_{16}$	9.75	5.3	-	-	7.48	0.04
β -Sesquiphellandrene	$C_{15}H_{24}$	-	-	25.73	0.81	-	-
β-Bisabolene	$C_{15}H_{24}$	28.53	0.37	24.50	0.96	-	-
β-Bourbonene	$C_{15}H_{24}$	-	-	18.55	0.09	-	-
β-Caryophyllene	$C_{15}H_{24}$	25.73	3.39	20.92	10.05	21.02	16.05
β-Elemene	$C_{15}H_{24}$	24.78	0.21	20.62	5.38	20.67	0.18
γ -Gurjunenepoxide-(1)	$C_{15}H_{24}O$	-	-	-	-	29.92	0.45
γ -Gurjunenepoxide-(2)	$C_{15}H_{24}O$	-	-	-	-	42.66	0.12
γ -Terpinene	$C_{10}H_{16}$	12.91	1.37	10.51	0.6	-	-
δ-Cadinene	$C_{15}H_{26}$	-	-	25.41	0.49	25.43	1.54
δ-Cadinol	$C_{15}H_{26}O$	-	-	38.86	0.41	-	-
Total			99.97		99.61		99.8

'–'indicates the absence of the compounds

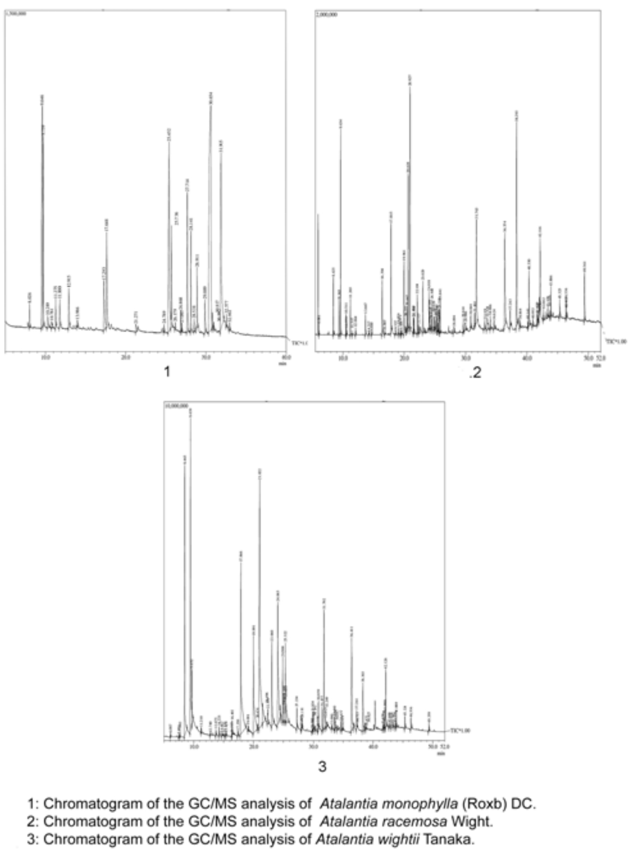

Fig 1. Chromatogram of GC/MS analysis of essential oils of three species of *Atalantia* genus

4. Conclusion

The present study evaluated the larvicidal activity of leaf essential oil of three species of genus *Atalantia*. Essential oils from all the species has the potential to be developed into eco-friendly larvicidal agents. Among the three, leaf essential oil of *A. racemosa* shows maximum activity against the three selected mosquito species namely *Culex quinquefasciatus*, *Anopheles stephensi* and *Aedes aegypti*.

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