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Research Article

Environmentally benign *Solanum torvum* (Sw.) (Solanaceae) leaf extract in ecofreindly management of human disease vector, *Aedes aegypti* (Linn.)

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ABSTRACT: Mosquitoes play a key role in the transmission of diseases such as malaria, yellow fever, Japanese encephalitis, etc. Plant based compounds form alternate source of control measures against mosquitoes, in view of deleterious effects of chemical pesticides. In the present study, insecticidal activity of aerial part of *Solanum torvum* (Sw.) was studied against *Aedes aegypti* (L.) under laboratory conditions. GC-MS study was analysed in hexane, ethyl acetate and methanol extract of *S. torvum* and the leaf extracts yielded around 57 compounds. In the larvicidal and adulticidal tests against *A. aegypti,* mortality rate increased with the increased concentrations of *S. torvum* extract. Highest larval mortality was obtained with ethyl acetate 100% extract at the dose of 200 µg/ml after 48 hrs experiment, followed by methanol 64% and hexane 42% leaf extract. The LC_{50} values of leaf extract was observed as 159.594 µg/mL, 182.272 µg/mL at 24 hrs interval and 85.2833 µg/mL, 138.472 µg/mL 48 hrs interval for ethyl acetate and methanolic extracts, respectively. In adulticidal activity highest mortality rate was obtained in ethyl acetate extract at 92% for the dose of 2 mg/ml after 24 hrs, followed by methanol 74% and hexane 52% leaf extracts. The LC_{50} values were 0.453 mg/mL, 0.790 mg/mL and 1.294 mg/mL with ethyl acetate, methanol and hexane extracts at 24 hrs interval against *Aedes aegypti*. In control treatment, no mortality rate was observed. Thus the present study showed the potential application of *S. torvum* leaf extract in the control of dengue mosquito under the laboratory conditions.

KEY WORDS: *Aedes aegypti*, ecofriendly management, *Solanum torvum,* vector

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INTRODUCTION

Chemical pesticides that include groups of herbicides, fungicides, rodenticides and insecticides are posing serious threat to the biodiversity and environment besides air and water pollution. Eddleston (2020) reported that every year about 1,50,000 people are dying because of chemical pesticide poisoning. The viable alternatives for conventional pesticides include use of biocontrol agents and plant essential oils for the management of insect pests (Ezhil Vendan et al. 2017).

Mosquitoes are the deadly insects responsible for transmitting the life threatening diseases like Japanese Encephalitis (JE), yellow fever, dengue fever, filariasis, malaria and schistosomiasis (Gubler, 1998). At present, more than 3,500 mosquito species under 41 genera are known to occur globally. *Aedes aegypti* (Insecta:Diptera:Culicidae) play an important role as vector in spreading the diseases in humans (Ghosh et al., 2012). Until now a large number of plant products are used against mosquito control. Different type of plants were used to control against *A. aegypti* which include, *Acorus calamus, Stemona tuberose, Derris elliptica, Rhinacanthus nasutus, Homalomena aromatic, Trigonostemon reidioides* extracts (Komalamisra et al. 2005), *Piper nigrum* extract (Rasheed et al., 2005); *Argemone Mexicana* extract (Sakthivadivel and Thilagavathy 2003); *Murraya koenigii, Coriandrum sativum, Ferula asafoetida* and *Trigonella foenumgraecum* (Harve et al., 2004); *Croton heliotropiifolius* and *Croton pulegiodorus* (Grace et al., 2010); *Euphorbia tirucalli, Jatropha curcas, Phyllanthus amarus, Pedilanthus tithymaloides* and *Euphorbia hirta* (Rahuman et al., 2008).

It is now necessary to control mosquitoes using ecofriendly management strategies to prevent pesticide associated problems. The management options with easily biodegradable substances were also carried out (Venkatachalam and Jebanesan, 2001; Choochote et al. 2004). Some plant-based nanoparticles are used as a good management, which poses less toxic effect on the environment (Kanayairam et al., 2013). Over 325 plants have been used to control *A. aegypti* (Kovendan and Murugan, 2011). Solanaceae are important medicinal plants in the families of Angiosperms and distributed widely in India, Pakistan, Tropical America and China (Nasir et al, 1985). In the world, 2000 Solanaceae species are available (Jennifer et al*.,* 1997). More than 12,000 alkaloids (nitrogen contains compounds) have been identified from plants so far. High level of glycoalkaloid, indole alkaloids, pyrrolizidine and tropane alkaloids compounds are widespread in plants of Solanaceae family and are naturally used in large quantities to control pests (Jerzykiewicz et al., 2007).

In the present investigations, mosquitoes larvicidal and adulticidal activity of different organic solvents of *S. torvum* leaf extract has been studied against *A. aegypti*.

MATERIALS AND METHODS

Rearing of *Aedes aegypti*

Patil et al. (2014) technique was adopted with slight changes in the rearing of *A. aegypti* larvae in our research study. The laboratory subculture of *A. aegypti* larvae was collected from the Kovilvenni near to Thanjavur district. 75 ± 5% relative humidity and 27 ± 2°C temperature was maintained in the laboratory conditions. The 3:1 ratio of dog biscuits and bakery yeast were used as feed to larvae. Finally, for well-matured adults 10% glucose solution and rat blood were used. The larvicidal and adulticidal bioassay studies were done in the recently emerged fourth instar larvae and adult mosquitoes.

Procurement of *Solanum torvum* and chemicals

The healthy aerial part of *S. torvum* was collected from the Kovilvenni near to Thanjavur district. The leaves were multi week air-dried and powdered by blender for the experimental study.

The cehmicals hexane, ethyl acetate, methanol, bakery yeast and glucose solution was purchased from Medox Biotech, India Pvt. Ltd.

Solvent extraction

The dried *S. torvum* leaf powder (5 kg) was extracted gradually with methanol, ethyl acetate and hexane as solvent in the soxhlet apparatus. Then, excess solvent was exhausted by a rotary vacuum evaporator under the temperature 60ºC. In the end, the obtained extract was stored in freezer for the futuristic purpose at 0ºC.

GC-MS analysis

The GC-MS study was carried out in a Berkin Elmer system equipped with a turbo mass Gold Mass spectrometer (Norwak, CD USA). GC-MS analysis Elite-5 capillary column (30 m x 0.25 mm, 0.25 film film thicknesses) was used. Helium served as the carrier fuel and all the samples have been analyzed via the following specifications; Initial temperature 40˚C for two min, Inj = 250˚C, ramp 5˚C/min to 290˚C, Split = 10:1, Volume = 1 µL, Delay: 5.00 min, Transfer Temperature = 200˚C, Source Temperature = 180˚C, Scan: 29 to 400Da. Compounds were identified using contrast of their respective mass spectra, retention indices (Kovats index) and above 40% of relative abundance of acceptance fit criteria with these of standards and with the aid of evaluating with the NIST mass spectral records system/ library.

Insecticidal Activity Studies

Larvicidal bioassay

Larvicidal approach was used to leaf extract of *S. torvum* against the *A. aegypti* (Al-Mekhlafi, 2018). Based on the preliminary experiments, methanol, ethyl acetate and hexane dissolved *S. torvum* leaf extract was used with five different concentrations (25, 50, 100, 150, and 200 µg/ml). Ten 4th instar *A. aegypti* larvae were released at the centre of standard 12- well tissue culture plates in 2 ml of tap water and five different concentrations of methanol, ethyl acetate and hexane extracts were used. After 24 and 48 hrs of exposure, the number of dead larvae and the percentage of mortality were noted. Likewise five replications were maintained. Methanol solvent was used as the negative control treatment. The corrected mortality rate of larvae (Abbott, 1925) was calculated.

$$\text{Corrected mortality} = \frac{\text{Observed mortality in treatment - Observed mortality in control}}{\text{100 - Control mortality}} \times 100$$

$$\text{Percentage mortality} = \frac{\text{Number of dead larvae}}{\text{Number of larvae introduced}} \times 100$$

Adulticidal bioassay

Ramkumar et al. (2016) method was adopted for the adulticidal bioassay of *A. aegypti*. The adulticidal bioassay for the *A. aegypti* was performed using a clean glass test tube and different concentrations of hexane, ethyl acetate and methanol extracts of *S. torvum* (0.1, 0.3, 0.5, 1 and 2 mg/ml) were used in the experiment and methanol was used as

control treatment. Different concentrations of organic solvent extract were coated with test tube and allow evaporation of the solvent. Five replicates were maintained for each experiment per concentration and 10 unfed female mosquitoes were released and then the test tubes were airtight and closed. *Aedes aegypti* mortality rate was determined after 24 hrs of exposure treatments.

Data analysis

The *A. aegypti* larvicidal and adulticidal mortality percentage was calculated using the method of Abbot's (1925). The 24 and 48 hrs exposure treatment and the correct mortality percentage were calculated by Tukey's multiple comparision test and analysis of variance. The LC_{50} and LC_{90} values were calculated using Graphpad Prism 8.4.1 software.

RESULTS AND DISCUSSION

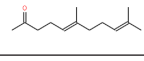
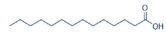
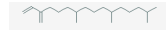
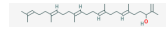
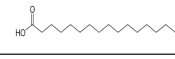
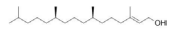
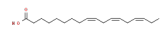
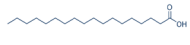
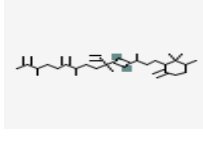
Chemical composition of *S. torvum* (Sw.) leaf extracts

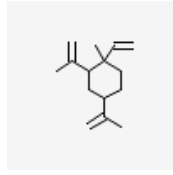
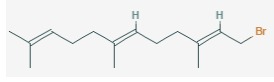
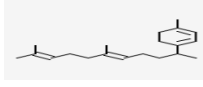
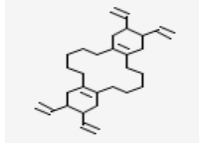
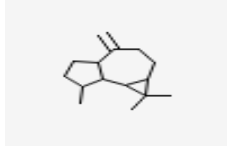
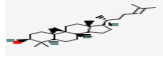
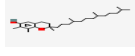
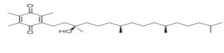
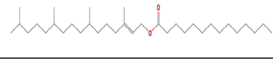
The GC–MS analysis of *S. torvum* leaf extracts enabled the identification of a total of 57 compounds. Overall, 34, 30 and 15 compounds representing 97.76, 89.946 and 85.32% in hexane, ethyl acetate and methanol leaf extract, respectively was recorded (Table 1).

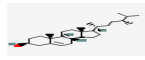
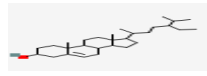
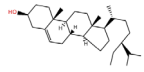
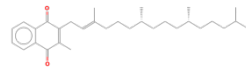
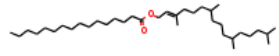
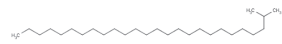
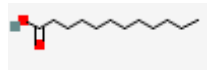
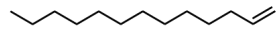
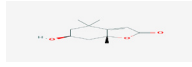
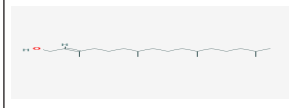
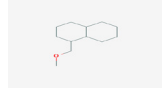
Larvicidal activity

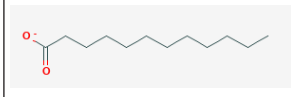
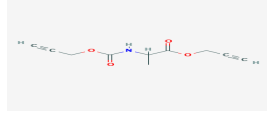
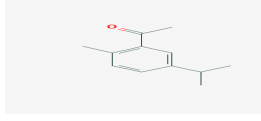
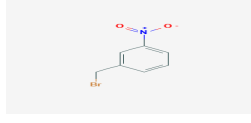
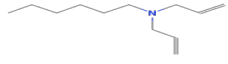
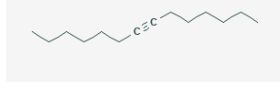
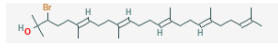
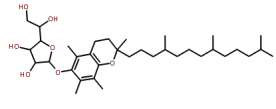
The larval mortality rate of ethyl acetate, methanol and hexane extracts of *S. torvum* at different concentrations (25–200 µg/ml) is presented in Table 2. Highest mortality rate, about 100% was achieved at higher concentration of 200 µg/ml of ethyl acetate extract of *S. torvum* after 48 hours of

Table 1. GC-MS analysis of hexane, ethyl acetate and methanol leaf extract of *S. torvum*

S.No	Name of compound	Reduction Time	Area %			Molecular Formula	Molecular Weight	Molecular Structure
			HE	EA	ME			
1.	Geranyl acetone	10.492	0.48	0.65	-	$C_{13}H_{22}O$	194.31 g/mol	
2.	Myristic acid	14.185	0.30	0.52	-	$C_{14}H_{28}O_2$	228.37 g/mol	
3.	Neophytadiene	15.004	0.48	0.77	3.17	$C_{20}H_{38}$	278.5 g/mol	
4.	1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-(.+/-.)-	15.774	1.04	0.82	-	$C_{30H50}O$	426.7174 g/mol	
5.	n-Hexadecanoic acid	16.32	3.84	6.47	13.56	$C_{16}H_{32}O_2$	256.42 g/mol	
6.	Phytol	17.71	4.45	7.91	11.28	$C_{20}H_{40}O$	128.1705 g/mol	
7.	Telfairic acid	17.79	2.53	-	-	$C_{18}H_{32}O_2$	280.4 g/mol	
8.	αLinolenic acid	18.014	3.13	4.93	15.27	$C_{18}H_{30}O_2$	278.436 g·mol^{-1}	
9.	Stearic acid	18.224	1.50	2.75	5.64	$C_{18}H_{36}O_2$	284.48 g/mol	
10.	Arachidic acid	19.955	0.26	-	-	$C_{20}H_{40}O_2$	312.5304 g/mol	
11.	1,1,6-trimethyl-3-methylene-2-(3,6,9,13-tetramethyl-6-ethenye-10,14-dimethylene-pentade	20.026	0.27	-	-	$C_{33}H_{56}$	452.8 g/mol	

S.No	Name of compound	Reduction Time	Area %			Molecular Formula	Molecular Weight	Molecular Structure
			HE	EA	ME			
12.	Cyclohexane, 1-methyl-2,4-bis(1-methylethenyl)-, (1.alpha.,2.beta.,4.beta.)-	20.107	1.09	-	-	$C_{15}H_{24}$	204.35 g/mol	
13.	1-Ethyltricyclo[5.2.1.1(2,6)]undec-8-en-11-ol	20.759	0.25	-	-	$C_{13}H_{20}O$	192.3 g/mol	
14.	Farnesyl bromide	20.861	4.67	-	-	$C_{15}H_{25}Br$	285.26 g/mol	
15.	geranyl-.alpha.-terpinene	21.564	0.42	-	-	$C_{20}H$	272.4681g/mol	
16.	Dibenzo[a,h]cyclotetradecene, 2,3,11,12-tetraethenyl 1,2,3,4,5,6,7,8,9,10	21.796	0.83	-	-	$C_{30}H_{44}$	404.7g/mol	
17.	Thunbergol	21.980	0.67	-	8.69	$C_{20}H_{34}O$	290.5g/mol	
18.	Cycloartanyl acetate	22.798	0.25	-	-	$C_{32}H_{54}O_2$	470.8g/mol	
19.	Squalene	23.417	3.88	1.67	-	$C_{30}H_{50}$	410.7g/mol	
20.	1H-Cycloprop[e]azulene, decahydro-1,1,7-trimethyl-4-methylene-	23.522	0.32		-	$C_{15}H_{24}$	204.35g/mol	
21.	4,8,13-Cyclotetradecatriene-1,3-diol, 1,5,9-trimethyl-12-(1-methylethyl)-	24.238	0.31	-	-	$C_{20}H_{34}O_2$	306.5g/mol	
22.	Decyl iodide	24.703	0.24	-	-	$C_{10}H_{21}I$	268.18g/mol	
23.	Cycloartenol	24.740	0.24	-	-	$C_{30}H_{50}O$	426.7g/mol	
24.	.gamma.-Tocopherol	25.030	0.43	-	-	$C_{28}H_{48}O_2$	416.7g/mol	
25.	alpha.-Tocopherolquinone	25.642	0.72	-	-	$C_{29}H_{50}O_3$	446.7g/mol	
26.	Phytyl tetradecanoate	25.755	0.25	-	-	$C_{34}H_{66}O_2$	506.9g/mol	

S.No	Name of compound	Reduc-tion Time	Area %			Molecular Formula	Molecular Weight	Molecular Structure
			HE	EA	ME			
27.	Campesterin	26.368	1.18	1.10	-	$C_{28}H_{48}O$	400.7g/mol	
28.	Phytosterol	26.599	2.71	2.93	-	$C_{29}H_{50}O$	414.7g/mol	
29.	.gamma.-Sitosterol	27.158	2.29	2.91	-	$C_{29}H_{50}O$	414.7g/mol	
30.	Phytonadione	27.382	0.38	-	-	$C_{31}H_{46}O_2$	450.7g/mol	
31.	Phytyl palmitate	27.516	1.18	-	-	$C_{36}H_{70}O_2$	534.9g/mol	
32.	2-Methylhexacosane	27.622	0.31	0.91	-	$C_{27}H_{56}$	380.7g/mol	
33.	Vitamin E	28.444	4.91	7.00	-	$C_{29}H_{50}O_2$	430.7g/mol	
34.	Tetrapentacontane	28.762	51.95	35.833	-	$C_{54}H_{110}$	759.4g/mol	
35.	Limona ketone	6.132	-	0.36	-	$C_9H_{14}O$	138.21g/mol	
36.	Vulvic acid	11.900	-	0.266	-	$C_{12}H_{24}O_2$	200.32g/mol	
37.	1-Tridecene	12.282	-	0.22	-	$C_{13}H_{26}$	182.35g/mol	
38.	Loliolide	14.308	-	0.46	-	$C_{11}H_{16}O_3$	196.24g/mol	
39.	1-Hexadecanol	14.551	-	0.60	-	$C_{16}H_{34}O$	242.44g/mol	
40.	3,7,11,15-Tetrame-thyl-2-hexadecen-1-o	15.451	-	0.26	-	$C_{20}H_{40}O$	296.5 g/mol	
41.	1-Nonadecene	16.608	-	0.65	-	$C_{19}H_{38}$	266.5g/mol	
42.	13-Tetradecen-1-ol acetate	18.490	-	0.40	-	$C_{16}H_{30}O_2$	254.41g/mol	
43.	3,7,11,15-Tetrameth-ylhexadec-2-en-1-yl acetate	18.654	-	0.33	-	$C_{22}H_{42}O_2$	338.6g/mol	
44.	Decalin, 1-methoxy-methyl-	20.108	-	1.17	-	$C_{12}H_{22}O$	182.3g/mol	
45.	Heneicosanol	20.215	-	0.32	-	$C_{21}H_{44}O$	312.6g/mol	
46.	Cycloeucalenol acetate	21.798	-	6.01	0.95	$C_{32}H_{52}O_2$	468.8g/mol	

S.No	Name of compound	Reduction Time	Area %			Molecular Formula	Molecular Weight	Molecular Structure
			HE	EA	ME			
47.	Octacosane, 1-iodo-	25.125	-	0.77	-	$C_{28}H_{57}I$	520.7g/mol	
48.	Phytyl dodecanoate	27.500	-	0.53	-	$C_{32}H_{62}O_2$	478.8g/mol	
49.	.beta.-Tocopherol, O-methyl-	28.429	-	0.53	-	$C_{29}H_{50}O_2$	430.7g/mol	
50.	D-Alanine, N-propargyloxycarbonyl-, propargyl ester	5.316	-	-	1.87	$C_{10}H_{11}NO_4$	209.2g/mol	
51.	Pyranone	6.308	-	-	2.75	$C_5H_4O_2$	96.08g/mol	
52.	5-Isopropyl-2-methylphenyl heptanoate	8.691	-	-	1.16	$C_{17}H_{26}O_2$	262.4g/mol	
53.	Benzene, 1-(bromomethyl)-3-nitro-	10.385	-	-	4.58	$C_7H_6BrNO_2$	216.03g/mol	
54.	Hexylamine, N,N-di(allyl)-	14.010	-	-	0.90	$C_{12}H_{23}N$	181.32g/mol	
55.	7-Tetradecyne	17.928	-	-	7.63	$C_{14}H_{26}$	194.36g/mol	
56.	6,10,14,18,22-Tetracosapentaen-2-ol, 3-bromo-2,6,10,15,19,23-hexamethyl-, (all-E)-	23.411	-	-	0.75	$C_{30}H_{51}BrO$	507.6g/mol	
57.	alpha.-Tocopherol-.beta.-D-mannoside	25.570	-	-	7.12	$C_{35}H_{60}O_7$	592.8g/mol	
Total		-		89.94	85.32			

HE - Hexane extract; EA - Ethyl acetate extract; ME - Methanol extract

Table 2. Larval mortality rate of *A. aegypti* at 24 and 48 hrs treatments in ethyl acetate, methanol and hexane leaf extract of *S. torvum*

Dosage µg/ml	Mortality Rate 24 hrs			Mortality Rate 48 hrs		
	Ethyl acetate	Methanol	Hexane	Ethyl acetate	Methanol	Hexane
25	18.00 ± 0.200	14.00 ± 0.244	00.00 ± 0.00	26 ± 0.244	22 ± 0.2	12 ± 0.2
50	26.00 ± 0.244	20.00 ± 0.316	12.00 ± 0.200	34 ± 0.244	30 ± 0.316	16 ± 0.244
100	34.00 ± 0.400	28.00 ± 0.200	22.00 ± 0.200	56 ± 0.224	42 ± 0.2	28 ± 0.2
150	46.00 ± 0.224	40.00 ± 0.316	26.00 ± 0.224	78 ± 0.2	52 ± 0.374	36 ± 0.224
200	66.00 ± 0.244	56.00 ± 0.244	38.00 ± 0.374	100 ± 0.00	64 ± 0.224	42 ± 0.374

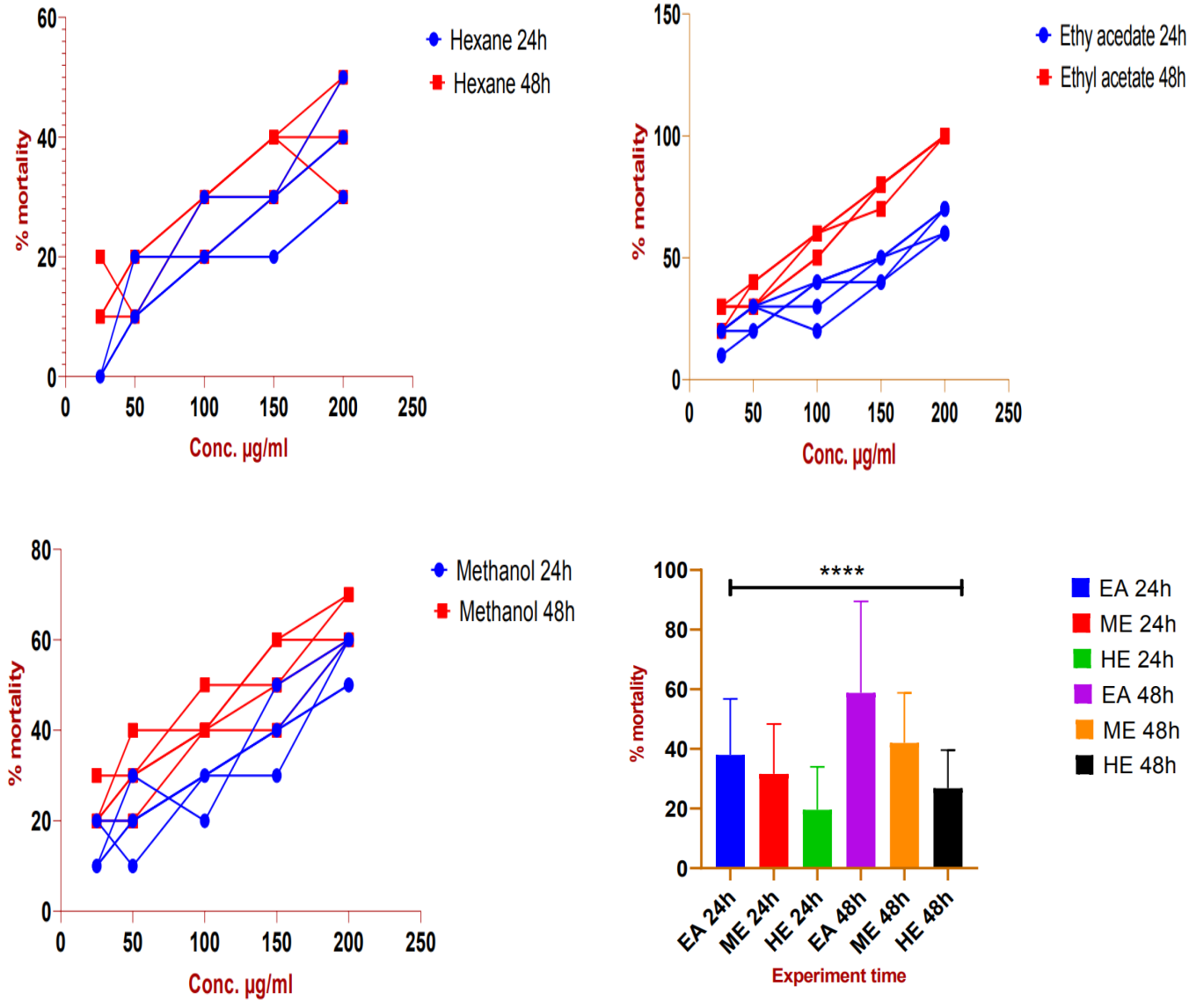


Fig. 1. (%) mortality rate of *S. torvum* against *A. aegypti* larva at different concentrations (µg/ml) with a different time interval. (ME) – Methanol, (EA) – Ethyl acetate and (HE) – Hexane.

treatment, followed by 64% at methanol extract and 42% at hexane extract *S. torvum*. Lowest larval mortality 00% was observed in hexane extract at the lowest treatment rate of 25 µg/ml after 24 hrs interval.

The individual mortality was achieved at methanol, ethyl acetate and hexane extract of *S. torvum* against *A. aegypti* and individual replicate with mean value was showed that the highest mortality rate in methanol extract at 24 and 48 hrs interval (**Figure 1**).

Figure 2 provides the LC_{50} and LC_{90} values of *S. torvum* extracts, LC_{50} value of ethyl acetate extract was most effective control agent against *A. aegypti* larvae (LC_{50} = 85.2833 µg/ml) followed by methanol extract with respectively (LC_{50} = 138.472 µg/ml)**.** The LC_{90} value of ethyl acetate extract only achieved at 175.468 µg/ml in 48 hrs of treatment against *A. aegypti* larvae**.** In our research, the larvicidal study repeated measures analysis of *S. torvum* against *A. aegypti* variance exposure treatment between the doses of 25, 50, 100, 150, and 200 µg/ml after 24 and 48 hrs treatment respectively significant at p <0.05 level (Table 3).

Adulticidal Bioassay

Highest adulticidal activity against *A. aegypti* was achieved 92% at higher concentration (2 mg/ml) of ethyl acetate extract after 24 hrs of treatment, followed by 74% at methanol extract of and 52% at hexane extract of *S. torvum*. Lowest contact toxicity 0.6% was observed in hexane extract at a lowest treatment rate of 0.1mg/ml after 24 hrs time intervals (Table 4).

The ethyl acetate leaf extracts were expressed the most toxic adulticidal effect against *A. aegypti* followed by methanol and hexane extract (Figure 3). LC_{50} analysis of the *S. torvum* ethyl acetate extract was the most effective control agent against *A. aegypti* (LC_{50} = 0.453 mg/mL) followed by methanol and hexane extract with respective LC_{50} values were 0.790 and 1.494 mg/mL and in the 24 hrs experiment, ethyl acetate extract LC_{90} values were 1.705 mg/mL (Figure 4).

The Tukey's multiple comparison test analysis of *S. torvum* against *A. aegypti* variance exposure between the doses of 0.1 0.3 0.5 1 and 2 mg/mL after 24 hrs respectively

Table 3. The larvicidal activity of *S. torvum* extracts repeated measures analysis against *A. aegypti*

	SS	DF	MS	F (DFn, DFd)	P value
Treatment (between columns)	30555	4	7639	F (4, 16) = 29.26	P<0.0001
Residual (within columns)	4177	16	261.1		
Total	34732	20			

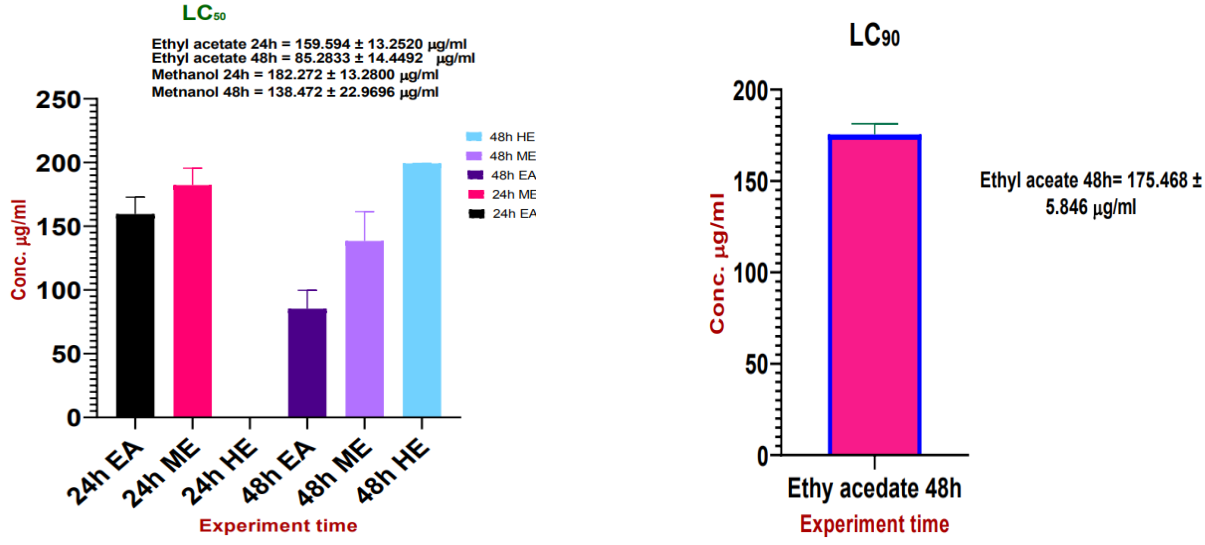


Fig. 2. LC_{50} and LC_{90} (µg/mL) values of *S. torvum* extracts against adult *A. aegypti* at different concentrations (µg/mL). (ME) – Methanol, (EA) – Ethyl acetate and (H) – Hexane.

Table 4. Adulticidal mortality rate of *A. aegypti* at 24 hrs treatments in ethyl acetate, methanol and hexane leaf extract of *S. torvum*

Dosage mg/ml	MORTALITY RATE at 24 hrs		
	Hexane	Ethyl acetate	Methanol
0.1	0.600 ± 0.244	24.00 ± 0.244	14.00 ± 0.400
0.3	16.00 ± 0.244	38.00 ± 0.374	28.00 ± 0.374
0.5	28.00 ± 0.200	54.00 ± 0.244	40.00 ± 0.547
1	40.00 ± 0.316	72.00 ± 0.374	54.00 ± 0.244
2	52.00 ± 0.220	92.00 ± 0.374	74.00 ± 0.509

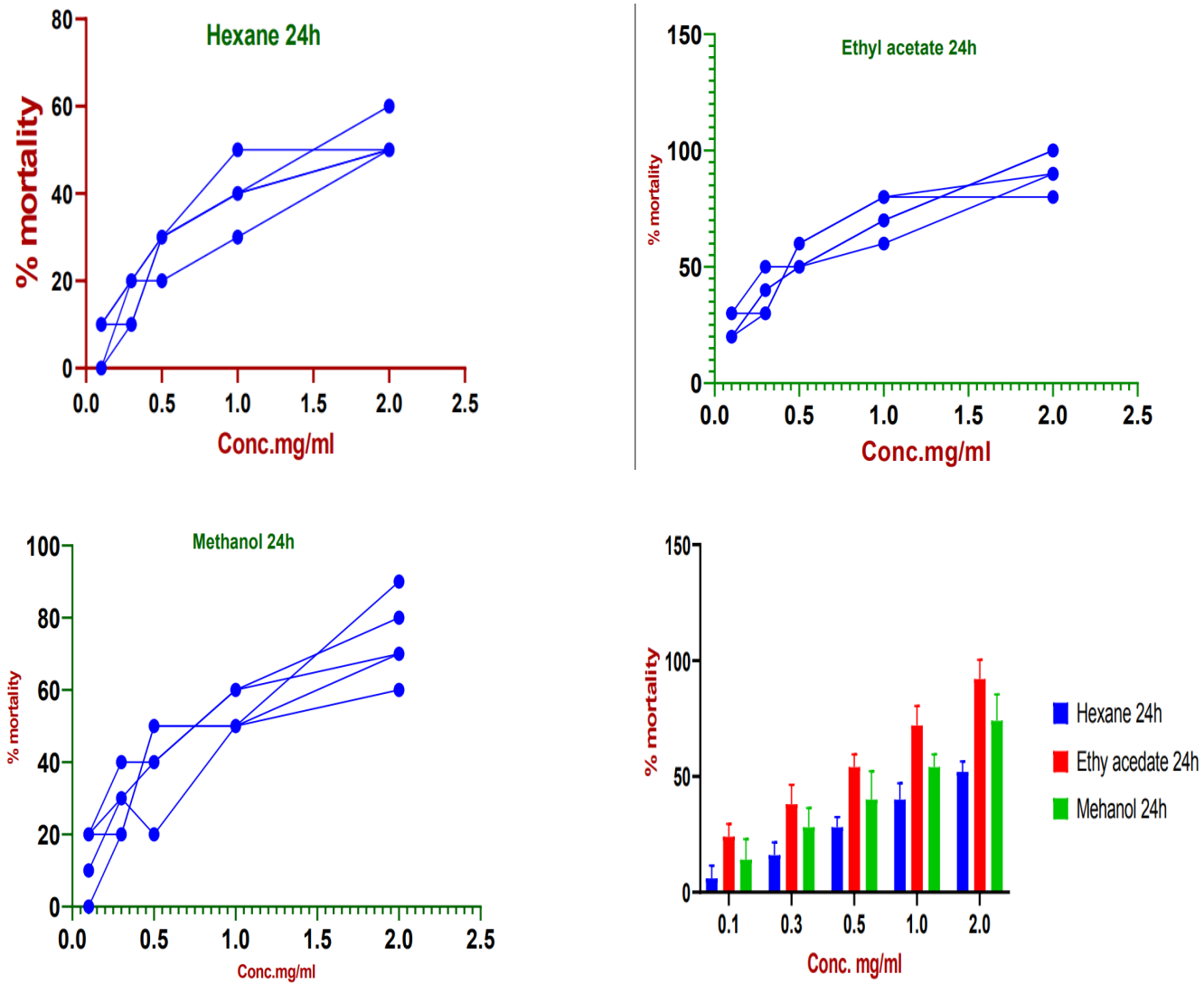


Fig. 3. The mortality rate of *A. aegypti* at different concentrations (µg/ml) with different time interval. (ME) – Methanol, (EA) – Ethyl acetate and (HE) – Hexane.

Table 5. Tukey's multiple comparison test analysis of *S. torvum* against *A. aegypti*

	Mean Diff.	95.00% CI of diff.		Significant	Summary	P Value
HE 24h vs. EA 24h	1.041	0.5575 to 1.524		Yes	***	0.0004
HE 24h vs. ME 24h	0.7033	0.2199 to 1.187		Yes	**	0.0066
EA 24h vs. ME 24h	-0.3375	-0.7561 to 0.08104		No	ns	0.1175

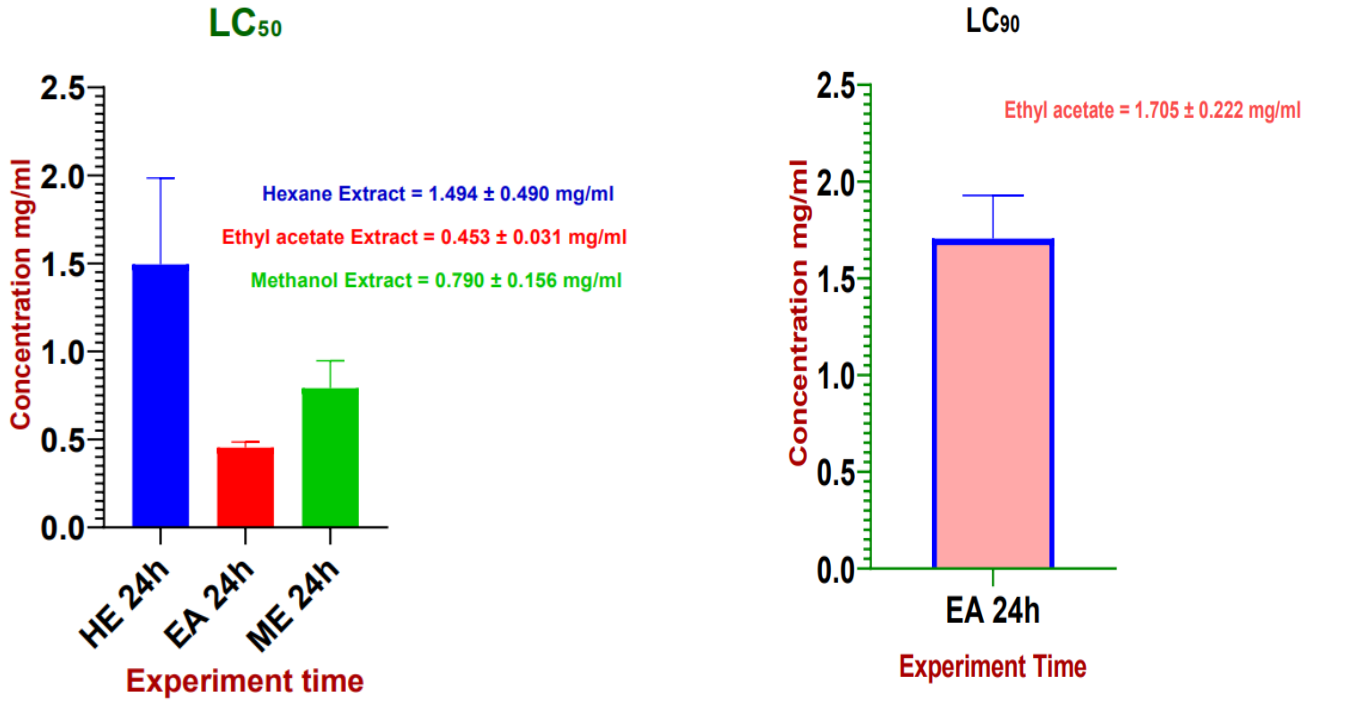


Fig. 4. LC_{50} and LC_{90} (µg/mL) values of *S. torvum* extracts against adult *A. aegypti* at different concentrations (µg/mL). (ME) – Methanol, (EA) – Ethyl acetate and (H) – Hexane.

and it was observed significant at p <0.05 level (Table 5).

Solanum torvum leaf extract resulted in sitosterol, 3, 4-trimethyl triacontane, 5-hexatriacontanone, octacosanyl-triacontanoate, tetratriacontanoic acid, Triacontanol, 3-tritriacontanone, stigmasterol, torvanol A and campesterol compounds (Mahmood et al., 1983). Additionally, Yuan-Yuan et al., (2011) identified a number of compounds, furostanol glycoside 26-O-beta-glucosidase, solagenin 6-*O*-*α*-L- rhamnopyranosyl- (1→3) -*β*-Dquinovopyranoside, solagenin 6-*O*-*β*-D-quinovo pyranoside, neochlorogenin 6-*O*-*α*-L-rhamnopyranosyl- (1→3)-*β*-D- quinovopyranoside, neochlorogenin 6-*O*-*β*-D-quinovopyranoside, quercetin, neochlorogenin 6-*O*-*β*-D- xylopyranosyl- (1→3) -*β*-Dquinovopyranoside, kaempferol and isoquercetin, rutin.

Various species of plants belonging to the Solanaceae family have been used against *A. aegypti.* Methanol fruit extract of *S. villosum* reporting an LC_{50} of 11.67 ppm (Chowdhury et al., 2009); aqueous extract of *S. nigrum* fruit with LC_{50} of 359 ppm (Raghavendra 2009); *S. xanthocarpum* fruit methanol extract with LC_{50} of 253.18 ppm (Mahesh Kumar et al., 2012); dichloromethanic leaves extract of *Cestrum nocturnum* against larvae (L3) reporting an LC_{50} of 30.12 ppm (Patil et al., 2011); *S. trilobatum* acetonic extract with LC_{50} of 125.67 ppm followed by chloroform extract with LC_{50} of 125.87 ppm and methanolic extract with LC_{50} of 125.43 ppm. AgNPs synyetized *S. nigrum* aqueous extract against third instar larvae of *Anopheles stephensi* and *Culex quinquefasciatus* obtaining a LC_{50} of 1.54 ppm and 2.44 ppm was reported (Rawani et al., 2013).

The present study was close to Muthukrishnan and Puspalatha (2001) reports, who stated that *Solanum suratense* leaf extract resulted in 50% adult mortality against *A. aegypti* and *A. stephensi*. About 50% mortality was obtained at 0.0586 and 0.812 mg/ml of *Luffa cylindrica* and *Solanum elaeagnifolium* extract (Renugadevi and Thangaraj, 2006).

CONCLUSION

Pesticides are highly toxic because they affect water, air and the environment. Mosquitoes are a major cause of disease for human and other animals too. Therefore, plant-derived compounds prevent mosquito vectors with ecofriendly manner. Controlling of mosquitoes has been a difficult task. Insecticide research on botanicals has increased nearly by 15% without promising products during the past decade. In India, phytochemical based pesticides for commercial use are very less and essential oil based insect pest control products are nil as per Central Insecticides Board and Registration Committee. According to current studies of mosquito control, natural compounds obtained from different parts of plants such as roots, bark, leaves, flowers, fruits, and seeds of various plants are being used (Vinayagam et al., 2008). In the present study the ethyl acetate leaf extract of *S. torvum* has shown good larvicidal and adulticidal activity, followed by methanol and hexane extract. So, the hexane, ethyl acetate and methanol leaf extracts of *S. torvum* has potent larvicidal and adulticidal efficacy against *A. aegypti*. In future, investigations of active compound of each extract needs to be identified for pesticide formulation against *A. aegypti.*

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