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Oviposition altering and ovicidal efficacy of root extracts of *Argemone mexicana* against dengue vector, *Aedes aegypti* (Diptera: Culicidae)

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ABSTRACT
Laboratory evaluations were carried out to evaluate the oviposition altering and ovicidal efficacy of root extracts of *Argemone mexicana* against the dengue vector *Aedes aegypti*. The extracts were prepared in five different solvents; petroleum ether, hexane, benzene, acetone and ethanol. Our studies established the efficacy of the non-polar extracts over the polar extracts. The oviposition deterrence studies established the petroleum ether root extract as the most efficient extract, with percent effective deterrence of 21% at 40 ppm reaching to 100% at 1000 ppm. The petroleum ether root extract also showed a high effectual deterrence at 100 ppm (ED% - 73%) at which other extracts were rendered comparatively ineffective. Most of the other extracts were not found to be significantly effective at lower concentration, but showed a gradual increase in the deterrent potential with increasing concentrations. On 24 h exposure of freshly laid eggs of *Ae. aegypti* with different root extracts, the non-polar extracts showed appreciable ovicidal potential at higher concentrations. The petroleum ether and hexane root extracts proved to be the most effective ovicides against *Ae. aegypti* eggs causing only 4.9 and 8.9% hatch respectively at the highest concentration. The benzene root extracts showed an appreciable decrease in the egg hatchability at higher concentrations, but could not sustain their ovicidal effect at lower concentrations. The polar extracts, however, were the least effective ovicidal agents.

Keywords: *Argemone,* reproductive fitness, oviposition deterrence, ovicidal, oviposition activity index, egg hatchability, effective deterrence.

1. Introduction
Vector-borne diseases are a major source of infirmity and decease worldwide. Mosquitoes, with the potential to transmit more diseases than any other group of arthropods, constitute a major public health problem as vectors of severe human diseases. Mosquito-borne diseases are prevalent in more than 100 countries across the world, infecting every year over 700,000,000 people globally and 40,000,000 of the Indian population [1]. Driven by the increasing number of reported cases year after year, the dengue fever mosquito, *Ae. aegypti*, continues to remain one of the most prevalent and serious disease vectors across the tropical and sub-tropical areas [2]. In India, Union health ministry reported a total of 50,222 dengue cases, which alarmingly increased to 75,454 cases causing 167 fatalities in 2013 [3].
For many years, the application of synthetic chemical insecticides has been the major tool in mosquito control operations. However, in recent years, use of many of the former synthetic insecticides in the mosquito control program has been limited as their continual use has disrupted natural biological control systems, leading to undesirable effects on non-target organisms and fostering environmental as well as human health concerns [4, 1]. Moreover, the selection pressure of these conventional insecticides has enhanced resistance of mosquito populations to insecticides at an alarming rate, thereby forcing the need to look out for environment-friendly and less toxic alternative strategies to target mosquitoes and keep mosquito-borne diseases under check.
Botanicals have emerged as successful alternatives to synthetic insecticides and are being proven as an efficient line of defense against the increasing mosquito-borne diseases. Phytochemicals have been reported to possess the potential to induce multiple effects against vector mosquitoes such as fecundity suppression, ovicidal activity, oviposition deterrence, growth inhibition, larvicidal, etc. [5, 6]. They are reported to be advantageous over the conventional chemical insecticides due to their eco-safety, target-specificity, non-development of resistance, reduced

number of applications, higher acceptability and suitability [7]. Nowadays the weeds, so-called nuisance plants, have attracted researchers' attention as eco-friendly substitutes to chemical insecticides for the management of the mosquitoes [6, 8]. This would not only resolve the problems concerning weeds, but also prove beneficial to mankind in a huge way. Only a limited number of reports are available regarding the potential of certain weeds as larvicides, ovicidal agents and oviposition deterrents against *Ae. aegypti* [5, 6, 8, 9, 10].

Present investigations were carried out against *Ae. aegypti* using a widespread, easily available weed, *A. mexicana*, commonly known as Mexican prickly poppy. The seeds of Mexican poppy have been known to have the potential of treating diseases like leprosy and jaundice [11]. The phytochemical extracts prepared from the leaves, stems and roots of *Argemone mexicana*, have been reported to possess larvicidal potential against *Ae. aegypti* [9]. These extracts have also proved to induce behavioural and morphological modifications in the larvae of *Ae. aegypti.* Researchers have also reported the larvicidal and chemosterilant activity of phytochemicals derived from *A. mexicana* seeds against *Ae. aegypti* [12].

The available literature reveals that this plant hasn't been explored extensively against mosquito vectors as ovicidal agents or oviposition deterrent. Hence, this study was undertaken to evaluate the credible use of root extracts of *A. mexicana* against *Ae. aegypti* in terms of their ovicidal efficacy and oviposition deterrence. The assessment of the mosquito control potential of this weed may be useful in formulating an appropriate strategy for the management of dengue vector and a new mosquito control agent.

2. Materials and Methods

2.1 Mosquito rearing

The present investigations employ the dengue fever mosquito, *Ae. aegypti*, originated from fields of Delhi and surrounding areas. The colony was maintained in an insectary at 28±1 °C, 80±5% RH and 14:10 L/D photoperiod [13]. Moist cotton pad was placed on the top of each cage to provide water for the adults. Water-soaked split raisins were kept in the cage as a source of the food for the male mosquitoes. Periodic blood meals were provided to female mosquitoes for egg maturation by keeping restrained albino rats in the cages. The eggs were collected in an enamel bowl lined with Whatman filter paper on all the sides and half-filled with de-chlorinated tap water. The eggs were allowed to hatch in trays filled with de-chlorinated water. Larvae were fed upon a mixture of finely ground dog biscuits and yeast in the ratio of 3:1 by weight. Care was taken to prevent the formation of any scum on the surface of water. The pupae formed were collected and transferred to the cloth cages for adult emergence.

2.2 Plant collection

The *A. mexicana* plant was collected from the surrounding areas in New Delhi, India. The roots were carefully separated from the plant and thoroughly washed with tap water. The disease-free, healthy roots were selected and dried under shade at room temperature of 27±2 °C for about 20 days. The dried roots were crushed, powdered and sieved thoroughly to get fine powder.

2.3 Preparation of the extract

The powdered root material was weighed and 200 g of the material was extracted in 1000 mL of petroleum ether, hexane, benzene, acetone, and ethanol, separately using soxhlet extraction apparatus. The extraction continued for 3 days, 8 h per day, at a temperature not exceeding the boiling point of the solvent. The five crude extracts, thus formed, were concentrated using a vacuum evaporator at 45 °C under low pressure. After complete evaporation of the solvent, the concentrated extracts were collected and stored in a refrigerator at 4 ºC as the stock solution of 1000 ppm for further use. The stock solution was used to prepare the desired concentrations of the extracts for investigating their oviposition deterrent and ovicidal potential against *Ae. aegypti*.

2.4 Oviposition deterrence studies

The oviposition deterrence studies were performed under controlled laboratory conditions using the multiple concentration test of the root extract. The experiment was conducted on twenty-five blood-fed females along with an equal number of males placed in a screen cage (45 x 40 x 40 cm). A number of oviposition cups lined with Whatman filter paper were introduced in the cage for oviposition, each of which was filled with 99 mL of de-chlorinated distilled water and 1mL of a particular concentration of the root extract. An oviposition cup containing 99 mL of de-chlorinated distilled water and 1mL of ethanol was also introduced in the cage which served as the control. The cups were left undisturbed in the cage until no further eggs were laid for at least 48 h. The position of each cup was changed each day to negate the position effect, if any. The eggs laid into each cup were collected separately and counted using a dissecting microscope at the magnification of 40X. Three replicates of each extract were carried out for the test.

The impact of the root extracts of *A. mexicana* on the egg laying capacity of female *Ae. aegypti* was assessed by calculating the fecundity rate per female at each concentration, by dividing the total number of eggs laid by total numbers of females present in the cage. The percent effective deterrence of each extract was evaluated by the following formula in order to estimate their potential to deter the females for egg laying.

$$ED\% = \frac{(NC - NT)}{NC} \times 100$$

Where, ED = effective deterrence, NC = number of eggs laid in control cups and NT = number of eggs laid in each experimental cup. The Oviposition Activity Index (OAI) of female *Ae. aegypti* was also calculated in each case using the following formula.

$$OAI = \frac{(NT - NC)}{(NT + NC)}$$

The results obtained were analyzed using Student's t-test with statistical significance considered for $P \leq 0.05$.

2.5 Ovicidal studies

The potential of all the five extracts prepared from the roots of *A. mexicana* was also assessed for their efficacy as ovicidal agents. The investigations were performed at 28 + 1 ºC on freshly laid eggs of *Ae. aegypti*. The freshly laid eggs were collected in de-chlorinated distilled water-filled oviposition cup lined with Whatman filter paper and counted using a dissecting microscope at the magnification of 40X.

The graded series of the root extracts were prepared using ethanol as the solvent. For conducting the ovicidal studies, 1 mL of a particular concentration of the extract was added to 99 mL of distilled water in a 250 mL glass jar. The mixture was shaken lightly to ensure a homogeneous test solution. A total of 250 freshly laid eggs of *Ae. aegypti* were counted, separated and transferred to glass jar containing distilled water for a thorough washing. This was done to ensure the removal of any leftover traces of the extract. The eggs were then transferred to distilled-water extract mixture and exposed for 24 h. Three replicates were

carried out simultaneously for each concentration of the extract making a total of 750 eggs for each test. Controls were exposed to the solvent, i.e. ethanol, alone. The exposed eggs were submerged in trays containing only de-chlorinated water and were allowed to hatch. The hatched larvae were counted and the percent hatch was calculated in each instance.

$$\text{Percent hatch} = \frac{\text{Number of hatched larvae}}{\text{Number of eggs exposed}}$$

The percent hatch in control was compared with the percent hatch in each concentration of the root extract. The results obtained were analyzed using Student's t-test with statistical significance considered for $P \leq 0.05$. After treatment, the eggs unable to hatch were scrutinized under light microscopy for any morphological alterations.

3. Results

Present studies evidently revealed the significant oviposition deterrent and ovicidal efficacy of the extracts prepared from the roots of *A. mexicana* against *Ae. aegypti* (Tables 1-4). The results also proved the considerable efficacy of the non-polar root extracts over the polar extracts.

Table 1: Effect of different concentrations of the root extracts of *Argemone mexicana* on the fecundity of *Aedes aegypti*

Extract	Concentration (ppm)									
	Control	**40**	**60**	**80**	**100**	**200**	**400**	**600**	**800**	**1000**
Petroleum ether	354.3 ± 11.9*a (14.17)	281.3 ± 5.8b (11.25)	210.3 ± 5.8c (8.41)	148.7 ± 3.9d (5.95)	95.7 ± 11.7e (3.83)	47.6 ± 4.9f (1.88)	24.6 ± 1.4g (0.98)	13.3 ± 2.3h (0.53)	4.0 ± 1.5i (0.16)	0.0 ± 0.0i (0.00)
Hexane	263.3 ± 26.2a (10.53)	279.7 ± 19.1a (11.19)	254.8 ± 8.3a (10.19)	239.3 ± 24.4ab (9.57)	182.0 ± 9.2b (7.28)	106.6 ± 10.5c (4.26)	61.0 ± 2.0d (2.44)	37.0 ± 2.3e (1.48)	21.6 ± 2.9f (0.86)	2.3 ± 1.4g (0.09)
Benzene	210.3 ± 10.8a (8.41)	253.7 ± 14.2a (10.15)	227.1 ± 0.3ab (9.08)	193.8 ± 12.6bc (7.75)	178.1 ± 4.2c (7.12)	166.0 ± 7.2c (6.64)	109.0 ± 8.1d (4.36)	68.3 ± 3.5e (2.73)	35.3 ± 7.2f (1.41)	11.3 ± 1.2g (0.45)
Acetone	330.6 ± 13.0a (13.22)	367.7 ± 10.3a (14.71)	345.6 ± 9.2ab (13.82)	327.9 ± 4.4b (13.12)	291.3 ± 0.5c (11.65)	276.6 ± 27.7bcd (11.06)	225.6 ± 7.6de (9.02)	152.0 ± 25.7e (6.08)	71.0 ± 7.7f (2.84)	32.3 ± 2.9g (1.29)
Ethanol	295.0 ± 12.3ab (11.8)	331.2 ± 20.0a (13.25)	305.9 ± 4.9a (12.24)	296.9 ± 15.6ab (11.88)	281.3 ± 3.1ab (11.25)	268.6 ± 15.6ab (10.74)	234.3 ± 21.9b (9.37)	153.6 ± 2.8c (6.14)	121.3 ± 9.3d (4.85)	66.3 ± 6.2e (2.64)

* The figures represent mean ± S.E.M.
Figures in parentheses indicate the fecundity rate of female adults at that particular concentration
Figures in each row followed by the same letter are not significantly different at $P = 0.05$ (Student's *t* test)

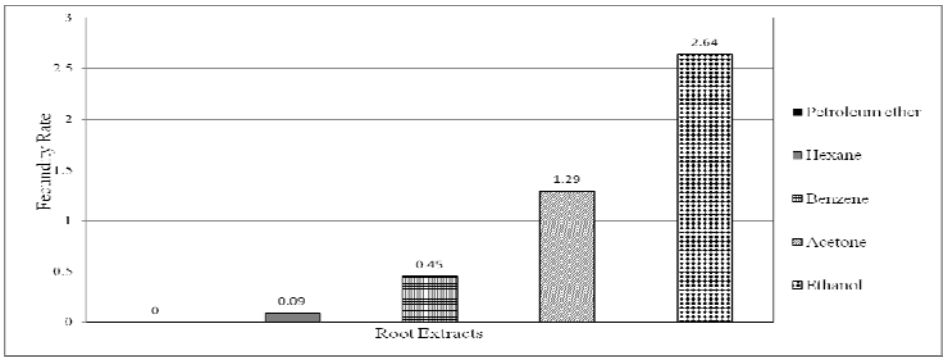

Fig 1: Impact of 1000 ppm root extracts of *Argemone mexicana* on the fecundity of *Aedes aegypti*

The studies proved the petroleum ether root extract as the most effective oviposition deterrent followed by the hexane, benzene, acetone and ethanol extracts in the order of decreasing efficiency. The petroleum ether extract caused a significant 21% ($P<0.05$; 0.005) decreased fecundity with 354 eggs laid in control as compared to 281 eggs laid at 40 ppm resulting in a negative OAI of

0.11 (Tables 2 and 3, Fig. 2). At the same concentration, other extracts were not found to be significantly effective oviposition deterrents (P>0.05). With gradual increase in the concentration, the deterrence gradually and significantly increased to 73% at 100 ppm with only 4 eggs laid per female as compared to 354 eggs laid in the control (P = 0.012) (Table 1, Fig. 1), the deterrence reaching to a 93% at 400 ppm (P = 0.0107).

Table 2: Percent effective oviposition deterrence (% ED) of the root extracts of *Argemone mexicana* against female adults of *Aedes aegypti*

Concentration (ppm)									
Extract	**40**	**60**	**80**	**100**	**200**	**400**	**600**	**800**	**1000**
Petroleum ether	20.6	40.6	58.0	73.0	86.5	93.05	96.2	98.8	100.0
Hexane	NR	3.23	9.11	30.9	59.5	76.8	85.9	91.8	99.1
Benzene	NR	NR	7.85	15.31	21.0	48.2	67.5	83.2	94.6
Acetone	NR	NR	0.81	11.89	16.3	31.7	54.0	78.5	90.2
Ethanol	NR	NR	NR	4.64	8.9	20.5	47.9	58.8	77.5

NR- Non-Repellent

Other root extracts, however, did not affect the oviposition activity of *Ae. aegypti* and were found to be non-deterrent at low concentrations. Nevertheless, with increased concentration, these extracts showed low level of deterrence ranging from 5-31% at 100 ppm which was 1.4-4.7 folds lower than shown by the petroleum ether extracts. Hexane extract exhibited a significantly effective deterrence of 59.5% at 200 ppm as against control (P = 0.0057); increasing to 66% at 600 ppm (P = 0.0014). The benzene and acetone extracts showed significant deterrent potential only at 600 ppm with only 68% and 54% ED, respectively (P <0.05; 0.0099 and 0.05). The ethanol extract did not prove to be a significantly effective deterrent at lower concentrations (P > 0.05), exhibiting appreciable negative OAI at 600 ppm (P = 0.0217).

Table 3: Oviposition activity index of the root extracts of *Argemone mexicana* against female *Aedes aegypti*

Concentration (ppm)									
Extract	**40**	**60**	**80**	**100**	**200**	**400**	**600**	**800**	**1000**
Petroleum ether	(-) 0.11	(-) 0.25	(-) 0.41	(-) 0.57	(-) 0.76	(-) 0.87	(-) 0.93	(-) 0.98	(-) 1.0
Hexane	(+) 0.03	(-) 0.02	(-) 0.05	(-) 0.18	(-) 0.42	(-) 0.62	(-) 0.75	(-) 0.85	(-) 0.98
Benzene	(+) 0.09	(+) 0.03	(-) 0.04	(-) 0.08	(-) 0.12	(-) 0.32	(-) 0.51	(-) 0.71	(-) 0.90
Acetone	(+) 0.05	(+) 0.02	(-) 0.004	(-) 0.06	(-) 0.09	(-) 0.19	(-) 0.37	(-) 0.65	(-) 0.82
Ethanol	(+) 0.06	(+) 0.02	(+) 0.003	(-) 0.02	(-) 0.04	(-) 0.11	(-) 0.32	(-) 0.42	(-) 0.63

*Positive and negative signs in parenthesis indicate decreased and increased oviposition deterrence, respectively

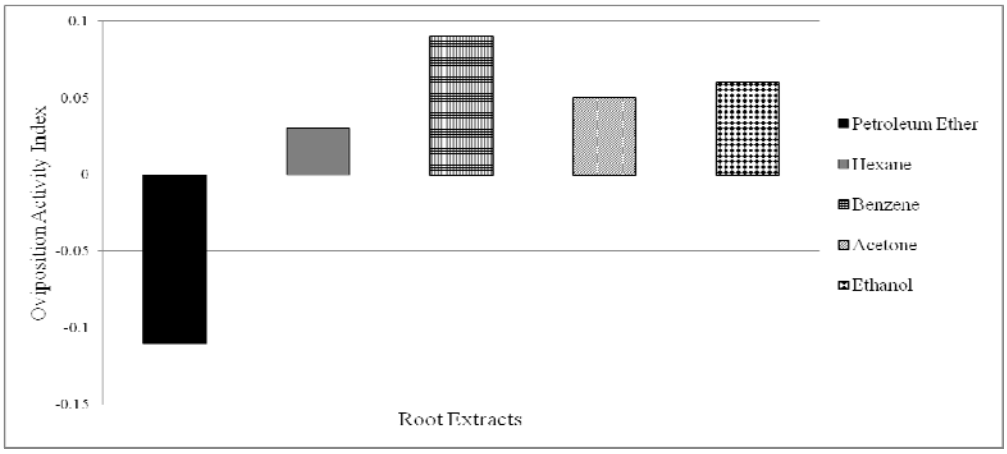

Fig 2: The Oviposition Activity Index of female adults of *Aedes aegypti* against 40 ppm root extracts of *Argemone mexicana*.

The investigations on ovicidal activity of root extracts showed a similar pattern as in the case of oviposition deterrence. The petroleum ether root extract was found to be the most effective ovicidal agent followed by hexane, benzene and acetone extracts (Table 4). The ethanol root extract proved to be the least effective among all the extracts tested. The investigations showed that all the extracts did not show any ovicidal activity at lower concentration which was found to increase considerably with increasing concentrations. The petroleum ether extract caused a significant reduced egg hatch of 23.67 % at 80 ppm as compared to 100% in

control (P = 0.095), the ovicidal potential sharply increasing to 75% at 600 ppm (P <0.05) which was 1.6 to 3.9-fold higher than the other extracts. At 1000 ppm, the petroleum ether extract resulted in only 4.9% hatch exhibiting 0.8 to 11.6-fold decreased egg hatch as compared to the other root extracts.

Table 4: Ovicidal effects of the root extracts of *Argemone mexicana* on freshly laid eggs of *Aedes aegypti*

	Concentration (ppm)									
Extract	**Control**	**40**	**60**	**80**	**100**	**200**	**400**	**600**	**800**	**1000**
Petroleum ether	100 ± 0.0*a	99.57 ± 0.5a	89.72 ± 2.2b	76.23 ± 7.1bc	72.27 ± 2.2c	55.82 ± 7.3cd	50.21 ± 5.2d	24.26 ± 4.0e	18.40 ± 2.9ef	4.85 ± 5.6f
Hexane	100 ± 0.0a	99.80 ± 4.2a	99.32 ± 10.5ab	98.79 ± 19.9ab	81.60 ± 4.4b	70.21 ± 2.3bc	59.90 ± 5.0c	40.08 ± 1.3d	24.86 ± 9.2de	8.97 ± 6.5e
Benzene	100 ± 0.0a	99.90 ± 4.0a	99.82 ± 1.2a	99.66 ± 4.3a	99.21 ± 9.9a	99.08 ± 1.1a	77.49 ± 0.3b	59.36 ± 3.4c	43.66 ± 4.1d	27.10 ± 0.3e
Acetone	100 ± 0.0a	99.69 ± 1.2a	98.78 ± 1.7a	98.59 ± 2.3a	98.48 ± 3.3a	98.68 ± 1.6a	98.39 ± 14.1ab	78.03 ± 1.8b	51.58 ± 0.5c	40.88 ± 1.1d
Ethanol	100 ± 0.0a	99.49 ± 14.9a	98.58 ± 2.8a	97.68 ± 2.2a	97.56 ± 2.8a	97.46 ± 1.6a	97.28 ± 12.3ab	95.42 ± 2.1ab	88.27 ± 1.6b	61.31 ± 1.0c

*Percent hatch ± S.E.M., calculated for 250 freshly laid eggs in each replicate
Figures in each row followed by the same letter are not significantly different at P= 0.05 (Student's t test)

Other extracts could not ascertain their ovicidal effect at lower levels, but caused an appreciable decrease in the egg hatchability at higher concentrations. The only other extract which was found to be a noticeable ovicidal agent was hexane root extract causing a significantly reduced hatch of 40% at 400 ppm as compared to control (P <0.05; 0.0013) (Table 4).

4. Discussion

Mosquito-borne diseases have become a widespread nuisance in many parts of the world. To resolve this problem, the quickest and most obvious alternate was the use of chemical synthetic insecticides. However, the continued and sustained use of these insecticides provoked undesirable effects, including toxicity to non-target organisms, environment and humans along with the development of resistance amongst the target population. Botanicals have now become the highlight of research as suitable alternatives to the harmful chemical insecticides. Plants are rich sources of complex mixtures of bioactive compounds that can be used to develop environmentally-safe vector and pest-managing agents [14]. In recent years, the use of plant products against mosquito control has been studied by various researchers [5, 6, 8].

The choice of an oviposition site by gravid mosquito females is a principal factor that determines species proliferation, population densities and dispersion in different geographical areas [15]. *Ae. aegypti* breeds in domestic and peridomestic water containers, follows visual and olfactory cues to find appropriate oviposition sites and then uses both physical and chemical factors of the waters to discriminate between suitable sites. Oviposition repellents cause mosquitoes to move away from the source, whereas, in the presence of oviposition deterrents, females move towards and land upon a site, assess site quality, but lay few or no eggs before flying away. In the present investigation, the significant oviposition deterrence of the non-polar extracts prepared from the roots of *A. mexicana* was clearly indicated against *Ae. aegypti*. Of all the five extracts studied, the petroleum ether root extract was found to be the most effective oviposition deterrent against female adults, resulting in 21% to 100% reduced fecundity at 40-1000 ppm against controls. Other extracts, though not so effective, were found to be reasonably effective oviposition deterrent against *Ae. aegypti*.

Our results are in conformity with the results reported by Kumar *et al*. [5] who revealed the efficacy of 1000 ppm non-polar diethyl ether leaf extract of *Parthenium hysterophorus* causing the maximum and significantly diminished fecundity in *Ae. aegypti* with 99.7% effective repellency. They also reported petroleum ether leaf extracts of the same plant to cause considerably high deterrence with a 94 % effective repellency at 1000 ppm. In 2010, Kweka *et al*. [16] studied the oviposition deterrence of essential oils extracted from *Ocimum kilimandscharicum* and *Ocimum suave* against gravid *Anopheles gambiae*. They reported the significantly increased oviposition in the control cups as compared to that in water containing oils.

The Oviposition Activity Index represents a global view of the relative preference of a substrate by gravid females [17]. Positive index values indicate more oviposition in the test cups than in control cups, whereas more eggs in the control cups as compared to the test cups result in negative index values. The negative OAI values, thus, indicate the preference of distilled water as the only medium for egg deposition over the treated medium which proved repulsive or unsuitable. Present investigation resulted in negative OAI values when petroleum ether root extracts of *A. mexicana* were used as oviposition medium. Kweka *et al*. [16] have also reported negative oviposition activity index ranging from (−) 0.19 to (−) 1.0 in water with *Ocimum* essential oils indicating the potential of *Ocimum* sp. to deter oviposition in *An. gambiae*. Our results have also revealed the considerable efficacy of the non-polar extracts prepared from roots of *A. mexicana* over the polar extracts. These are contrary to the results of Rajkumar and Jebanesan [18] who asserted the efficient oviposition deterrence of a polar ethanolic leaf extract of *Cassia obtusifolia* against the malarial vector. They reported maximum effective repellency of 92.5% against oviposition at 400 mg/l followed by 87.2%, 83.0% and 75.5% noted in 300, 200 and 100 mg/l, respectively.

Oviposition is one of the most important events in the life cycle of mosquitoes, as prevention of oviposition reduces their population. The deterrence of various extracts prepared from different parts of *A. mexicana* observed in *Ae. aegypti* clearly indicates that these mosquitoes were acutely sensitive to chemical stimuli and respond to the odour of the extract. It suggests that improved knowledge of mosquito oviposition behavior could allow formulation of effective oviposition deterrents for reduction of mosquito populations in the future.

It is also well known that the ovicidal potential of phytochemicals can form effective grounds for management of mosquitoes. Our

investigations showed that when 24 h exposure of freshly laid eggs of *Ae. aegypti* were exposed with different root extracts of *A. mexicana*, the petroleum ether extract resulted in 50% reduced hatch at 400 ppm, the ovicidal efficacy increasing at 1000 ppm only 4.9% egg hatch. It was also observed that the hexane root extract could result in only 8.9% hatch at 1000 ppm establishing its ovicidal potential. The percent hatch in eggs exposed to 1000 ppm of other extracts for 24 h, however, ranged from 27.1% to 61.3% with the ethanol extract proving to be the least effective. Our results suggest the presence of certain bioactive components in the extracts which could arrest the fertility. Sakthivadivel and Thilagavathy [12] also revealed 100% failure of the egg hatching on treatment with ethanolic seed extracts of *A. mexicana* against *Ae. aegypti*. Similar studies by Kumar *et al.* [5] revealed that the diethyl ether and benzene extracts of the leaves of *P. hysterophorus* resulted in 100% egg mortality in *Ae. aegypti* causing no larval emergence after 24 h of exposure. The petroleum ether extract, however, exhibited moderate ovicidal effect of 41%, resulting in 59% hatch.

The leaf extracts of *Cassia fistula* prepared in different solvents have also been reported as efficient ovicides leading to 100% egg mortality in *Ae. aegypti* [19]. Govindarajan *et al.* [20] reported zero egg hatchability at 400 mg/L of methanolic leaf extract and 625 mg/L methanolic seed extracts of *Pithecellobium dulce* against *An. stephensi* and *Ae. aegypti*, respectively. Panneerselvam and Murugan [21] assessed the ovicidal potential of the crude hexane, ethyl acetate, benzene, aqueous, and methanol solvent extracts of *Andrographis paniculata*, *C. occidentalis* and *Euphorbia hirta* against *An. stephensi* and reported 100% egg mortality caused by polar methanolic extracts of *A. paniculata* at 150 ppm and; methanolic extracts of *C. occidentalis* and *E. hirta* at 300 ppm.

In recent years, the use of various plant products against mosquito control has been studied by several researchers [22, 23, 24]. Our results elucidate the significant and variable efficiency of various extracts prepared from roots of *A. mexicana* as potential oviposition deterrent and ovicidal agent against *Ae. aegypti*, the petroleum ether extract proving to be the most potent extract followed by hexane extracts. However, the mechanism causing these impacts is still unknown and needs to be investigated. Variety of types and levels of active constituents in each extract may be responsible for the variability in their potential against *Ae. aegypti*. As *A. mexicana* is an easily available weed in many different parts of the tropical region, its commercial exploitation to form anti-mosquito products may have the advantage of being cost-effective boosting the local economy. Further studies of the formulated preparations for enhancing potency and stability, toxicity and effects on non-target organisms and the environment, and field trials are needed to recommend *A. mexicana* as eco-friendly botanical for use in mosquito control program replacing the harmful conventional insecticides.

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