



## MOSQUITOCIDAL ACTIVITIES OF *SALVIA LEUCANTHA* LEAF EXTRACT AGAINST FILARIAL VECTOR, *CULEX QUINQUEFASCIATUS* SAY (DIPTERA: CULICIDAE)

Radhika, N. and Jeyabalan, D.

Department of Zoology, Government Arts College, Udthagamandalam- 643 002  
The Nilgiris, Tamil Nadu, India

### Abstract:

Mosquitoes act as a vector for most of the life threatening diseases like malaria, yellow fever, dengue fever, chikungunya fever, filariasis, encephalitis, West Nile Virus infection, etc. The continuous application of synthetic insecticides causes development of resistance in vector species, biological magnification of toxic substances through the food chain and adverse effects on environmental quality and non target organisms including human health. Application of active toxic agents from plant extracts as an alternative mosquito control strategy was available from ancient times. These are non-toxic, easily available at affordable prices, biodegradable and show broad-spectrum target-specific activities against different species of vector mosquitoes. This research aimed to investigate mosquitocidal activities of *Salvia leucantha* plant leaves with ethanol extract against *Culex quinquefasciatus*. The extract showed remarkable larvicidal, pupicidal, adulticidal, oviposition deterrent, adult emergence, repellency and biting deterrence against *C. quinquefasciatus*. *Salvia leucantha* leaf extract is the most effective mosquito larvicide which is manifested by the highest percentage mortality on the larvae of 100% at 2% concentration of leaf extract. *Salvia leucantha* showed a significant difference on the increased of the mortality of mosquito larvae with increasing concentrations of the plant extracts. The high mosquitocidal activity of *Salvia leucantha* leaf is supported by the abundance of phytochemicals which show synergistic effects in terms of larvicidal action to mosquito larvae. *Salvia leucantha* affected pupal and adult mortality and also affected the reproductive potential of surviving adults by reducing the number of eggs laid and the percentage of egg hatchability. When each larval stage was treated with plant extracts, the younger instar larvae were found to be very susceptible to *Salvia leucantha*. These extracts delayed larval development and inhibited adult emergence. From the outcome of the present investigation that the ethanol extract of *Salvia leucantha* plant possesses strong larvicidal, pupicidal, adulticidal, oviposition deterrent, adult emergence inhibitory activities, repellency and biting deterrence against *C. quinquefasciatus*.

### Key words

*Salvia leucantha*, *Culex quinquefasciatus*, larvicidal, pupicidal, adulticidal, reproductive activity, repellent.

### 1. INTRODUCTION

Mosquitoes are the utmost important solitary group of insects in terms of public health importance and is placed in the respective order Diptera and family *Culicidae*. To date, there are around 3,601 named mosquito species recognized worldwide and placed under respective nomenclature which represents a diverse and medically important fly family *Culicidae* (Wilkerson *et al.*, 2015). The family *Culicidae* based on molecular and genetic information, is a monophyletic family with two divergent subfamilies *Anophelinae* and the *Culicinae* (Pawlowski *et al.*, 1996; Miller *et al.*, 1997). The *Culicidae* are splinter of a large group of primitive lower Diptera, the nematocerans, presently placed in the infraorder *Culicomorpha* (mosquitoes, biting and non-biting midges, and black flies).

Mosquitoes are distributed all over the world, except in Antarctica. Members of the arthropod genus *Anopheles*, *Culex* and *Aedes* are most ordinarily liable for bites in humans. Mosquitoes are flying and biting insects that progress in water during their immature stages. To mature, mosquitoes require an environment of standing water. As a group, they need custom made environment to

complete their life cycle in various aquatic habitats, including fresh water, saline-water marshes, brackish water and water found in containers, old tyres, or tree holes, etc.,. The life cycle of mosquito has four distinct stages: the egg, larvae, pupa and adult.

When tracking the biological life history of *Culex quinquefasciatus* mosquito, it informs us that there is a close association with humans, and their frequency of occurrence in populated areas around the globe. *Culex quinquefasciatus* Say, generally prefers subtropical climates (Farajollahi *et al.*, 2011). *Culex quinquefasciatus* are commonly observed entering human dwellings, giving rise to the common apt name “house mosquito” (Reisen, 2012). *Culex quinquefasciatus* is an autogenous mosquito, requiring mammalian erythrocyte from the formed elements of fluid connective tissue of our body during their blood meal for the development of eggs for each gonotrophic cycle. Female *Culex quinquefasciatus* prefers to oviposit in dirty, sediment rich, human-made water, most notably above and below ground waste water systems wherever it is applicable to have standing water (Reisen, 2012). Gravid mosquitoes lay their non-cleidoic eggs in floating “rafts” consisting of up to 150 eggs (Roberts and Kokkinn, 2010), depending on blood meal source and female age. Biological developmental rates of *Culex quinquefasciatus* are largely determined by temperature, with warmer temperatures decreasing time to adulthood (Rueda *et al.*, 1990). Eggs generally hatch within two to three days of oviposition, with larvae progressing through four instars (1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>& 4<sup>th</sup> instars) over the course of approximately a summation of ten days. During larval developmental instar stages, these mosquitoes feed upon microorganisms and micro detritus suspended in the water column, including dust, bacteria, unicellular algae, and small protozoans (Merritt *et al.*, 1992). Following anephemeral pupal stage, adult males emerges from the water principally, followed shortly thereafter by females. Both male and female mosquitoes require sugar intake to obtain energy necessary for flight, to help development of gametes by gametogenesis, and to mate with their counterpart (Foster, 1995). After mating, female *Culex quinquefasciatus* mosquitoes seek out blood, and undergo a gonotrophic cycle lasting approximately two to three days (Elizondo *et al.*, 2006). Gravid females seek out acceptable water sources to oviposit and the cycle begins again (Gupta *et al.*, 2017)

World Health Organisation has stated the mosquitoes as “public enemy number one” (WHO, 2014). Mosquitoes borne disease are widespread in more than 100 countries across the world, infecting over 70,000,0000 people every year globally and 40, 000, 0000 of Indian population (Bavani *et al.*, 2015). Disease transmission through *Culex quinquefasciatus* occurs when they are infected with a pathogen (infectious agents like bacteria, protozoa, viruses and helminthes) when blood feeding on the reservoir host (a vertebrate where pathogens complete their life cycle). The pathogen transmitted through vectors replicates and the infected mosquito acts as vector and transmits it when taking further blood-meals from other vertebrates. This type of transmission is called horizontal transmission of diseases in vector biology.

Lymphatic filariasis is a serious public health problem in India, constituting one third of the infected inhabitants of survey globally. *Culex quinquefasciatus* is a vector of lymphatic filariasis which is most widely disseminated tropical disease and there are nearly 1,100 million people living in areas which is highly prone to the risk of endemism for lymphatic filariasis and the ease of risk of infection (Priyanka *et al.*, 2019), *Wuchereria bancrofti* accounts nearly for 90% of all filariasis cases in the world, followed by *Brugia malayi* and *Brugia timori*. India adds up about 40% of the total global burden of filariasis and accounts for about 50% of the people at risk of infection. Recent estimates have shown that in India, 20 states and 5 union territories were found to be endemic for filariasis and nine states (Andhra Pradesh, Bihar, Gujarat, Kerala, Maharashtra, Orissa, Tamil Nadu, Uttar Pradesh and West Bengal) contributed to about 95% of the total burden of filariasis, thereby posing a threat of infection to about six hundred million people (NVBDCP, 2018). Lymphatic filariasis is in the list of one of the most important neglected tropical diseases, being the second leading cause of permanent and long-term disability in the world. India stands second after South Africa in the endemicity and transmission intensity of the disease (Bharathi and Saha, 2018).

Filariasis symptoms are revealed by acute and chronic inflammation of the lymphatic tissue system. The disease development results from the host's immune response to the presence of filarial worms in the lymphatic tissues, which cause lymphatic blockage and chronic oedema of the affected parts (elephantiasis). Clinically it is expressed by recurrent fever and inflammatory response of lymphatic vessels and glands, orchitis trailed by hydrocele, or abscesses in limb lymphatic system especially in the lower part of the limbs. Consequences of filariasis with respect to abdominal lymphatics oedema, which often results in the passage of milky white urine (chyluria) or chylous ascites. In some groups of population a tropical pulmonary eosinophilia syndrome may be a feature. This syndrome is characterised by an abnormal immune response in the lungs which leads to cough and shortness of breath with eosinophilic lung infiltrates and peripheral blood eosinophilia

Reducing the spread of mosquito-vectored pathogens is often performed by regulating mosquito populations rather than directly targeting the pathogen transmitted through vectors. Mosquito control can be accomplished in several ways. Adults can be allured away mechanically (Okumu *et al.*, 2010), trapped (Reiter, 1983), sprayed with adulticides (Farajollahi *et al.*, 2012), or deterred from biting by active utilization of repellents (Katz *et al.*, 2008). Larvae can be treated with a variety of larvicides, surface tension breaking by using thin film of oils (Corbet *et al.*, 2000), or managed through prevention of stagnation of source water (Rose, 2001). Most of the insecticides which are used as pesticides and mosquitocides available in the markets are synthetic chemical derivative products, which, apart from their extortionately high costs, with their non judicial applications on the environment have unpremeditated implication including the production of increasing resistant strains of mosquitoes on a global scale, ecological imbalance, higher rate of biological magnification through food chain in our ecosystem and elimination of non-target organisms in the environment (Anyaele and Amusan, 2003; Russel and Skilleter, 2009).

According to Bowers *et al.* (1995), the screening of locally available medicinal plants for pest and vector control would generate employment locally to the residents, reduce the rapid dependence on highly expensive and imported vector control products and stimulate local efforts to reinforce the public health system globally. The botanical pharmacological approaches used in the search of new bioactive toxins from plants appear to be predictive compared to the random screening approach. Plants have secondary metabolites which are required for interaction with the environment and confirmed to have biological activity and that can be helpful in protecting the plants from diseases and insect pests. These compounds can be divided into different chemical groups like alkaloids, phenolic, terpenoids, rare amino acids, plant amines and glycosides. Due to presence of these compounds, which have the potency against mosquitoes there are possibilities to search such plant extracts which can be effective against the mosquitoes. There are many other plant extracts which are being used against different stages of mosquitoes. Plant extracts and essential oils from these sources is sure shot the best alternative novel approach against synthetic or chemical insecticides for the control of disease causing vectors (Bilal *et al.*, 2012). Numerous plant species and different parts of the plants have been exploited, throughout the world to control the mosquito populations (Muthukrishnan *et al.*, 1997).

Medicinal plants are very effective in mosquito control. A variety of plants are reported to contain insecticidal compounds (Grainge and Ahmed, 1988). Secondary metabolites which are obtained from the indigenous plant sources has proven to precede with mosquito control potential can be used as an alternative line of attack to synthetic or chemical insecticides under the integrated pest and vector control programmes locally and globally. The chemicals derived from plants have been projected as weapons in future mosquito control program as they are shown to function as insect growth regulators, repellents, and ovipositional attractants, having deterrent activities observed by different investigators working towards pest and vector control programme (Murugan *et al.*, 1996; Venkatachalam and Jebanesan, 2001; Choochote *et al.*, 2004; Okumu *et al.*, 2007) studied the mosquitocidal potential of natural products as larvicides against the African malarial vector, *Anopheles gambiae*. Gas chromatography analysis of the essential oil from the fiddleheads of *Pteridium aquilinum* showed the presence of 40 compounds that consisted mainly of alkanes (86.60%), monoterpenes (3.20%) and sesquiterpenes (2.40%).

The mosquito larvicidal activity of  $\beta$ -estradi-sterol isolated from *Abutilon indicum* was studied by Rahuman and Venkatesan (2008). The isolated and identified  $\beta$ -sitosterol has a potential to act as a new mosquito larvicidal compound with LC<sub>50</sub> value of 11.49 ppm, 3.58 ppm and 26.67 ppm against *Aedes aegypti*, *Anopheles stephensi* and *Culex quinquefasciatus* respectively. Dhar *et al.* (1996) reported the effect of neem oil volatiles on gonadotrophic cycle and inhibition of oviposition in *Anopheles stephensi* and *Anopheles culicifacies*. Jayabalan *et al.* (2003) analysed the mosquitocidal effect of methanolic extracts of *Pelargonium citrosa* tender leaves for their biological, larvicidal, pupicidal, adulticidal, anti-ovipositional activity, repellency and biting activity of *Anopheles stephensi*. Murugan *et al.* (2003) evaluated the larval toxicity of botanical pesticides such as Neem (*Azadirachta indica*), Pongam (*Pongamia pinnata* (L.)), Thumbai (*Leucas aspera*) on the filarial vector, *Culex quinquefasciatus*.

Murugan *et al.* (2012) in his detailed study evaluated the larvicidal, pupicidal, repellent and adulticidal biological activity of *Citrus sinensis* orange peel extract against three mosquito species namely *Anopheles stephensi*, *Aedes aegypti* and *Culex quinquefasciatus*. Su and Mulla (1998) reported the ovicidal activity of the neem product azadirachtin against the mosquitoes *Culex tarsalis* and *Culex quinquefasciatus*. Ovicidal effects of the seed extract of *Atriplex canescens* were reported against *Culex quinquefasciatus* (Ouda *et al.*, 1998). Plants are also used as insect repellents against mosquitoes, may also play a vital role in the control of the malaria (Mohammed, 2009). Many plants produce secondary components that have insect growth inhibitory activity. Indeed, many plant extracts were analyzed to kill larvae of different species of mosquitoes (Girdhar *et al.*, 1988). The phytochemicals derived from plant sources can act as larvicides, insect growth regulators and repellents (Alakarmalai Jeyasankar *et al.*, 2012). Arivoli *et al.* (2012) reported the larvicidal activity of seven plant extracts against the 3<sup>rd</sup> instar larvae of *Anophelus stephensi*.

Therefore in the present study we have screened *Salvia leucantha* leaves extract on the larvicidal, pupicidal, adulticidal, larval, pupal and adult duration, reproductive activity, repellency, biting deterrence and biochemical constituents of *Culex quinquefasciatus*. The potential result of the present study would be useful in promoting research and analysis aiming at the development of new agent for mosquito control support based on bioactive compounds from indigenous endemic medicinal plant source.

## 2. MATERIALS AND METHODS

### 2.1 Collection and preparation of plant extracts

Healthy leaves of *Salvia leucantha* were collected from Nilgiri hills of Tamilnadu, India. The plants were identified with the help of experts in the Department of Botany, Government Arts College, Udahgamandalam and standard books. The collected plant materials were washed in tap water, cut into small pieces and air dried. After the plants were completely dry, they have been ground into powder and then macerated in solvents (ethanol) at room temperature for 3 days and filtered. The combined filtrate were concentrated to dryness by rotary evaporation at 50°C and kept in a freezer. In preparing test concentrations, plant extract was volumetrically diluted in ethanol.

### 2.2 Mosquito culture

Mosquito larvae/eggs of *Culex quinquefasciatus* have been collected in an around Ooty. The mosquito colonies were maintained at 27 ± 2 °C, 75-85% relative humidity index a 14:10 light/dark photo period cycle (Murugan and Jeyabalan, 1999).

### 2.3 Larvicidal and Pupicidal assays

Larvae tested for the present study was obtained from our laboratory culture. Freshly hatched or moulted larvae were used for the bioassay tests. The required quantity of plant extract concentrations were mixed thoroughly with 200 ml of rearing water in 500ml plastic troughs. One hundred early fourth instars mosquito larvae were released into each trough. Larvae food consisted of 1g of finely ground dog biscuits per day per trough. Dried coconut midribs were place over water as the substratum for pupation. The plastic trough containing 200 ml of rearing water with solvent served as the control. Dead larvae and pupae was removed and counted at 24 h intervals. Observations on larval and pupal mortality were recorded. The experiment was replicated five times. Percentage mortality observed in the control was subtracted from that observed in the treatments (Abbot, 1925). The day from moulting of the larvae to pupation and to adulthood was noted. Fecundity was assessed by counting the number of eggs laid during the life span by control and experimental mosquitoes. The larvae and pupal duration of treated and control individuals were compared and developmental rates were determined.

### 2.4 Adulticidal assay

*Culex quinquefasciatus* fresh adults were exposing to filter paper treated with different concentration of plant extract. The paper was keep inside the beaker. Muslin cloth covering the beaker was also treated. Control insects were exposed only to distilled water with solvent treated paper and muslin cloth. Mortality count was taken after 24h (Sharma *et al.*, 1992).

### 2.5 Ovipositional assay

Different quantities of plant extract from a stock solution were mixed thoroughly with 200 ml of rearing food in 250 ml glass jars to obtain the concentration desired for the tests with *Culex quinquefasciatus*. The gravid females were given a choice between treated and control jars. During the tests, the groups of females were kept separate for 48 h in cages measuring 25 x 25 x 30cm. After the eggs were counted the oviposition activity index (OAI) was calculated using the formula:

$$OAI = \frac{(N_c - N_t)}{(N_c + N_t)} \times 100$$

Where  $N_c$  is the number of eggs in the control

$N_t$  is the number of eggs in the treatment

### 2.6 Ovicidal assay

*Culex quinquefasciatus* eggs were released in water. The test extracts were added in desired quantities and hatching were observed for one week. The eggs were then exposed to deoxygenated water and the numbers of hatching eggs were recorded. Percentage hatching was compared with the control in which only distilled water with solvent were used (Sharma *et al.*, 1992).

### 2.7 Repellency activity

Different concentrations of plant extract were mixed thoroughly with 10ml of goat blood in glass plates. The untreated blood served as the control. Adult females were release into each cage. The number of females landing on the treated blood and untreated blood were record. The repellent index of the plant extracts were calculated as described by (Murugan and Jeyabalan, 1999).

### 2.8 Biting deterrency activity

The percentage protection in relation to dose method was used (WHO, 1996). Blood starved female *Culex quinquefasciatus* (100 nos), 3 - 4 days old, was kept in a net cage (45x30x45 cm<sup>2</sup>). The arm of the test person was cleaned with isopropanol. After air drying the arm, a 25 mc<sup>2</sup> area of the dorsal side of the skin was exposed, the remaining portion was covered by rubber gloves. The plant extracts were dissolved in ethanol, where distilled water with solvent served as control. Different concentration of the plant extracts was applied. The control and treated arms was introduced simultaneously into the cage. The numbers of bites was count over 5 minute from 6 pm to 6 am. The experiment was conducted five times. The percentage protection was calculated by using formula:

$$\text{Percentage protection} = \frac{(\text{No. of bites received by control arm}) - (\text{No. of bites received by treated arm})}{(\text{No. of bites received by control arm})}$$

### 2.12 Statistical analysis

All data was subject to analysis of variance and the treatment mean was separated by Duncan's Multiple Range Test (Duncan, 1955). Statistical analysis was carried out using the (Statistical Package Social Science) SPSS software, version 16.0.

### 3. RESULTS

In our present study the leaf extract of *Salvia leucantha*, are grinded with solvent ethanol was tested for larvicidal activity against *Culex quinquefasciatus* at variable and increasing concentration of 0.5%, 1%, and 2%, and the mortality were recorded for each instar stages and represented in the form of table 1. It has been observed that *Salvia leucantha* registered mortality values of 55%, 48%, 39% and 35% respectively with 1<sup>st</sup> instar, 2<sup>nd</sup> instar, 3<sup>rd</sup> instar and 4<sup>th</sup> instar larval stages at 0.5% treatment. *Salvia leucantha* registered mortality values of as follows: 73%, 62%, 56 % and 49% respectively with 1<sup>st</sup> instar, 2<sup>nd</sup> instar, 3<sup>rd</sup> instar and 4<sup>th</sup> instar larval stages at 1% treatment. Similarly the outbound record of *Salvia leucantha* recorded with 100%, 95%, 87% and 80% respectively with 1<sup>st</sup> instar, 2<sup>nd</sup> instar, 3<sup>rd</sup> instar and 4<sup>th</sup> instar larval stages at 2% treatment. It has also been observed that the 1<sup>st</sup> and 2<sup>nd</sup> instar larval forms requires smaller concentration to bring out the mortality, than the 3<sup>rd</sup> and 4<sup>th</sup> instar larval forms, which requires a comparatively high concentration (%) of the extract to bring out the mortality. Thus, larval mortality is directly proportional to the concentration and the response of every instar with leaf extract of experimental plant with ethanol is entirely unique and variable among the developmental stages in larval form.

**Table 1. Effect of ethanol leaf extracts of *Salvia leucantha* on the larval mortality of *Culex quinquefasciatus***

S. No	Treatment	Concentration (%)	1 <sup>st</sup> Instar (%)	2 <sup>nd</sup> Instar (%)	3 <sup>rd</sup> Instar (%)	4 <sup>th</sup> Instar (%)
1.	Control	00	00 <sup>d</sup>	00 <sup>d</sup>	00 <sup>d</sup>	00 <sup>d</sup>
2.	<i>Salvia leucantha</i>	0.5	55 <sup>c</sup>	48 <sup>c</sup>	39 <sup>c</sup>	35 <sup>c</sup>
		1	73 <sup>b</sup>	62 <sup>b</sup>	56 <sup>b</sup>	49 <sup>b</sup>
		2	100 <sup>a</sup>	95 <sup>a</sup>	87 <sup>a</sup>	80 <sup>a</sup>

Within a column means followed by the same letters are not significantly different at 5% level by the DMRT

The biological parameters such as pupal mortality, adult mortality and adult emergence of *Culex quinquefasciatus* with solvent extracts at three varied concentrations (0.5%, 1% and 2%) of *Salvia leucantha* represented table 2. The test plant was subjected to experimentation and the pupal mortality was recorded. It was observed that if there is an increase in the concentration of the test samples resulted in increase in mortality. No mortality was recorded in respective control replicates within the experimental conditions as expressed in percentage. *Salvia leucantha* displayed a significant pupal mortality, at all the concentration subjected in the study. Even at 0.5% concentration, *Salvia leucantha* exposes 52% pupal mortality. As the concentration increased, the pupal mortality also increased with range of 52% to 88% at varied concentration. Thus, a dose relation response was observed with direct relationship.

The adult mortality (%) of *Culex quinquefasciatus* at various concentrations of ethanol extracts of *Salvia leucantha* is represented in table 2. Our experimented plant showed significant mortality in bioassays with ethanol extracts. The plant extracts at 0.5% concentration *Salvia leucantha* exhibited least adult mortality of 48%, followed by this the next higher mortality of 58% at 1% and 79% at 2% treatment. It was also noted that when compared with pupal mortality, adult mortality was comparatively lower for all treatments. Thus in this observation as there is an increase in concentration, there exhibited directly an increased adult mortality, exhibiting a direct relationship with the concentration.

The adult emergence from pupae after permanent acquaintance to experimental plant leaves with ethanol extracts is represented in table 2. It is likewise fascinating to annotate that in the given laboratory conditions, the plant exhibited efficient reduction in adult emergence, in comparison with the control. In the study, at all the concentrations (0.5%, 1% and 2%), adult emergence of *Salvia leucantha* at substantially recorded the value of 75%, 66% and 55% respectively. Thus the given experimental plant has significantly reduced the adult emergence when compared to the control. In the present investigation, it was a dose dependent action, where progressive increase in the concentration of the extracts is indirectly proportional to the adult emergence. When compared this result with pupal mortality and adult mortality there exhibited a direct relationship with increase in concentration and analogous result with adult emergence of *Culex quinquefasciatus*.

**Table 2. Effect of ethanol leaf extracts of *Salvia leucantha* on the pupal mortality, adult mortality and adult emergence of *Culex quinquefasciatus***

S. No	Treatment	Concentration (%)	Pupal mortality (%)	Adult mortality (%)	Adult emergence (%)
1.	Control	00	00 <sup>d</sup>	00 <sup>d</sup>	100 <sup>a</sup>
2.	<i>Salvia leucantha</i>	0.5	52 <sup>c</sup>	48 <sup>c</sup>	75 <sup>b</sup>
		1	65 <sup>b</sup>	58 <sup>b</sup>	66 <sup>c</sup>
		2	88 <sup>a</sup>	79 <sup>a</sup>	55 <sup>d</sup>

Within a column means followed by the same letters are not significantly different at 5% level by the DMRT

**Table 3. Effect of ethanol leaf extracts of *Salvia leucantha* on adult repellency and ovipositional deterency of *Culex quinquefasciatus***

S. No	Treatment	Concentration(%)	Adult Repellency (%)	Oviposition Deterency (%)
1.	Control	00	00 <sup>d</sup>	00 <sup>d</sup>
2.	<i>Salvia leucantha</i>	0.5	32 <sup>c</sup>	38 <sup>c</sup>
		1	54 <sup>b</sup>	52 <sup>b</sup>
		2	75 <sup>a</sup>	84 <sup>a</sup>

Within a column means followed by the same letters are not significantly different at 5% level by DMRT.

Results of laboratory testing of plant extracts of *Salvia leucantha* were screened for adult repellency (%) and ovipositional deterency (%). Adult repellency (%) and ovipositional deterency (%) for ethanol leaf extracts is represented in table 3. In respect to ethanol extract, all the concentrations of plant have the potential adult repellency and ovipositional deterency when compared to control. Adult repellency (%) with respect to *Salvia leucantha* recorded 32%, 54% and 75% respectively for the increasing concentration of 0.5%, 1% and 2%. It is evident from the recorded data that the adult repellency is significantly increased with increased in concentration and *Salvia leucantha* remarked the maximal adult repellency.

When analyzing the obtained result of ovipositional deterency (table 3) with ethanol leaf extract, the ovipositional deterency is significantly increased and at 2% concentration *Salvia leucantha* recorded 84% of ovipositional activity. It is manifest for us to say that the given plant extract has a promising ovipositional deterency (%) with a dose related response. Thus Adult repellency (%) and ovipositional deterency (%) is directly proportional to the dosage as there is increased concentration, brings about increase in the respective activity.

**Table 4. Larval duration of *Culex quinquefasciatus* after the treatment of ethanol leaf extracts of *Salvia leucantha*.**

S. No	Treatment	Concentration (%)	1 <sup>st</sup> Instar (days)	2 <sup>nd</sup> Instar (days)	3 <sup>rd</sup> Instar (days)	4 <sup>th</sup> Instar (days)
1.	Control	00	1.5 <sup>d</sup>	2.8 <sup>d</sup>	3.7 <sup>d</sup>	4.4 <sup>d</sup>
2.	<i>Salvia leucantha</i>	0.5	3.1 <sup>c</sup>	4.2 <sup>c</sup>	5.3 <sup>c</sup>	6.4 <sup>c</sup>
		1	5.2 <sup>b</sup>	7.8 <sup>b</sup>	7.9 <sup>b</sup>	8.5 <sup>b</sup>
		2	7.0 <sup>a</sup>	9.5 <sup>a</sup>	9.4 <sup>a</sup>	10.5 <sup>a</sup>

After the treatment of mosquito *Culex quinquefasciatus*, the treated mosquito's larvae were assessed for their larval duration. The plant ethanol extracts of *Salvia leucantha* are screened. The larval duration of *Culex quinquefasciatus* after the treatment of plant extracts with ethanol is given in table 4. Combatively it was observed that the larvae took supplementary time to mature into pupae in all the treatments when associated to the crude clutches - control. At maximum concentration of 2% with the solvent extracts of plant gave extended larval duration in all the instars equated with the control, the total developmental period was observed to be amplified with increasing concentration of treatments. Dose – response relationship was determined for plants functional to *Culex quinquefasciatus*. Increase in the concentration of the extracts, upsurges in the developmental period, which clearly reveals the dose – response relationship. The duration of larval instars and the total developmental time were prolonged. The possible reason could be a harmonic mimic; on the other hand we are not aware of the exact mechanism to reveal this effect.

**Table 5. Pupal and adult duration of *Culex quinquefasciatus* after the treatment of ethanol leaf extracts of *Salvia leucantha***

S. No	Treatment	Concentration (%)	Total pupal duration (days)	Total adult duration (days)
1.	Control	00	3.5 <sup>c</sup>	58 <sup>a</sup>
2.	<i>Salvia leucantha</i>	0.5	5.4 <sup>c</sup>	45 <sup>b</sup>
		1	7.8 <sup>b</sup>	34 <sup>c</sup>
		2	10.3 <sup>a</sup>	22 <sup>d</sup>

Within a column means followed by the same letters are not significantly different at 5% level by DMRT.

The developmental metamorphosis for pupae and adult developmental duration (days) was recorded for the plant with ethanol extracts of *Salvia leucantha*. The observed results for ethanol leaf extract are presented in the table 5. Analysis of the adult *Culex quinquefasciatus* developmental metamorphosis against plant extracts of ethanol, time taken for total larval and pupal developmental periods (in days) were considerably inhibited. Analysis of ethanol extracts of plant with respect to pupal and adult duration (days) signifies that it is concentration dependent. The recorded a pupal and adult duration for *Salvia leucantha* treatment at 0.5%, 1% and 2% concentration is as follows: 5.4 days, 45 days; 7.8 days, 34 days; and 10.3 days, 22 days respectively. Increase in the concentration from 0.5%, 1% and 2% results in increase the total pupal duration which signifies a direct relationship with the concentration, at the same decrease in total adult duration (days) which shows an inverse relationship with the concentration gradient.

**Table 6. Effect of ethanol leaf extract of *Salvia leucantha* on fecundity and egg hatchability of *Culex quinquefasciatus***

S. No	Treatment	Concentration (%)	Fecundity (No. of eggs)	Eggs hatchability (%)
1.	Control	00	211 <sup>a</sup>	100 <sup>a</sup>
2.	<i>Salvia leucantha</i>	0.5	153 <sup>b</sup>	65 <sup>b</sup>
		1	122 <sup>c</sup>	48 <sup>c</sup>
		2	95 <sup>d</sup>	35 <sup>d</sup>

Within a column means followed by the same letters are not significantly different at 5% level by DMRT.

Action of ethanol extracts of *Salvia leucantha* on fecundity (no. of eggs laid) of *Culex quinquefasciatus* were obtained from the general stock of mosquitoes and tested in relation to the different concentrations of ethanol at 0.5%, 1% and 2% (Table 6). Our selected plant of Nilgiris had a promising effect on *Culex quinquefasciatus*. When analyzing the number of eggs laid after the treatment of plant extracts with ethanol, it was observed that at all the concentration, the plant exhibited promising efficient effect on the fecundity. To the extent of increase in concentration from 0.5%, 1% and 2% of *Salvia leucantha* extracts recorded 153, 122 and 95 numbers of eggs respectively. Thus it can be dogged that as the concentration increases, the fecundity (no. of eggs) decreases which is an inversely proportional result and a substantial result obtained in our study. Thus *Salvia leucantha* exhibits potent decrease in fecundity in comparison with treated groups with respect to control in the laboratory condition.

Action of ethanol extracts of *Salvia leucantha* on hatching of *Culex quinquefasciatus* eggs freshly laid were obtained from the general stock of mosquitoes and tested for their hatching ability (%) in relation to the different concentrations of ethanol at 0.5%, 1% and 2%. It has been noted that as the concentration increases, the egg hatchability substantially decreases. *Salvia leucantha* registered with 65%, 48% and 35% of egg hatchability, which signifies that the egg hatchability decreases with increase in concentration, exhibiting a dose dependent inverse relationship.

Table 7. Effect of ethanol leaf extract of *Salvia leucantha* on Larval-pupal intermediate of *Culex quinquefasciatus*

S. No	Treatment	Concentration (%)	Larval-pupal Intermediate (%)
1.	Control	00	00 <sup>d</sup>
2.	<i>Salvia leucantha</i>	0.5	35 <sup>c</sup>
		1	54 <sup>b</sup>
		2	76 <sup>a</sup>

Within a column means followed by the same letters are not significantly different at 5% level by DMRT.

In our present study, we enumerated the larval-pupal intermediate (%) of *Culex quinquefasciatus* with various increasing concentration (0.5%, 1% and 2%) of ethanol leaf extracts of *Salvia leucantha* and the same represented data in table 7. Analysis of larval – pupal intermediate (%) of *Culex quinquefasciatus* with ethanol extracts showed promising detrimental effect. The larval-pupal intermediate of *Salvia leucantha* disclosed 35%, 54% and 76% intermediates, with increasing concentration of 0.5%, 1% and 2%. Thus increase in concentration of the extracts, increased the retention of *Culex quinquefasciatus* in larval – pupal intermediate stage with ethanol leaf extracts. This analysis clearly indicates that lower concentration of the plants with solvent effectively produced clear morphological growth disruption in the treated mosquito larvae, pupae and adults compared to controls, which showed normal structural sorts. Several forms of morphological distortions resulted from treatment of larvae, pupae and adults with the extracts. The apodous larvae showed several types of morphological distortions; deformed mouth brushed, melanised and sclerotized cuticles. The pupae that survived through larval treatment showed a variety of malformation like complete de-melanised pupae with straight abdomen, partly melanised pupa with extended abdomen, dwarf pupa with retarded abdomen, de-chitinised pupa with distorted terminals.

Table 8. Effect of ethanol leaf extract of *Salvia leucantha* on biting deterency of *Culex quinquefasciatus*

S. No	Treatment	Concentration (%)	Biting deterency (%)
1.	Control	00	00 <sup>d</sup>
2.	<i>Salvia leucantha</i>	0.5	32 <sup>c</sup>
		1	51 <sup>b</sup>
		2	78 <sup>a</sup>

Within a column means followed by the same letters are not significantly different at 5% level by DMRT.

Effects of plant extracts with experimental solvent against *Culex quinquefasciatus* was examined for biting deterency (Table 8). In this observation, the crude extracts of solvent gave protection against mosquito bites without any allergic reaction to the test persons and also the biting deterency activity is dependent on the concentration of the plant leaf extracts. When analyzed the effects of ethanol extracts against *Culex quinquefasciatus* on biting deterency, against 0.5%, 1% and 2% concentrations, it was observed that *Salvia leucantha* recorded highest biting deterency of 32%, 51% and 78% respectively. So when cumulatively analyzed the solvent biting deterency was recorded highest in ethanol extracts in comparable control.

#### 4. DISCUSSION

Mammalian body fluid tissue (blood) sucking female mosquitoes are responsible or the more intolerance nuisance with respect to the biting and the transmission of large number of diseases to mammals, among them the most dreaded ones are malaria, yellow fever, dengue, filariasis, encephalitis and chikungunya, results in severe health related issues and obstacles to socio-economic development in both developed and developing countries, particularly in the tropical regions (Murugan *et al.*, 2007) of the biosphere. Mosquito control is a complex networked and expensive task, frequently requiring the co-operation efforts of communities, as well as industrial groups, agricultural bodies of local, state and central governments. Synthetic pesticides, of today's generation often adversely had a drastic impact on the environmental abiotic and biotic factors which includes targeted and non-targeted organisms; and resistance towards these chemical pesticides by genetic mechanism of knock out or in of genes in their genetic flow of information (Becker *et al.*, 2010). Mosquito control using plant based origin has been considered as high priority for research and development of safe, biodegradable, nonbiomagnifiable and environmental friendly mosquitocides. Singh *et al.* (2001), Kamaraj *et al.* (2009), Dias and Moraes, (2014) and Hauda *et al.* (2019) have reported that the mosquitocidal activity and chemical composition of *Calendula*, *Rauwolfia*, *S. gluinosa*, *L. origanoides*, *Citrus colocynthis*, *Cucurbita maxima*, *T. vulgaris* species vary considerably depending on geographical conditions, photosensitivity, photoperiodism, vernalisation, and type of solvent used for extraction of essential oils.

In the present study ethanol leaf extracts of *Salvia leucantha* was assessed and found to be more toxic to immature stages of *Culex quinquefasciatus*. The early instar larval forms were more susceptible to the given extracts than the latter larval forms and pupae, which was not much affected by the solvent, but still proved to be potential against *Culex quinquefasciatus*. This finding is similar to Mittal *et al.* (1995) and Thambusamy *et al.* (2008), that methanolic leaf extract of plant have significant larvicidal activity of I and II instar larval forms, when compared to III and IV instar larval forms when working with *Zingiber officinalis*.

When analyzing the efficacy of the solvent extracts from our finding, the data obtained co-insides with the finding of Sukumar *et al.* (1991) where methanolic extracts were more toxic than petroleum ether and acetone. Several plant extracts with the suggestions of (Al Dakhil and Morsy, 1999; Cetin and Yani, 2006; Hamouda *et al.*, 1996; Nathan *et al.*, 2006; Kannathasan *et al.*, 2007 and Vatandoost and Vaziri, 2004) lined with our results that the IV instar larval forms is less susceptible to the given extracts, which may be due to the non-feeding behaviour of IV instar and pupae.

Bisset *et al.* (2014) have found that there was significant difference in the mortality when compared to aqueous and polar solvents as most of the solute particles having mosquitocidal activity are soluble in polar solvents compared to aqueous extract and the mosquitocidal activity is due to the plant extract and not the solvents. Thus, the solubility of phytochemicals in suitable polar solvents is highly essential and research based studies are required. Based on this our result proved that compared to control groups, the treated groups with the solvents viz., methanol, petroleum ether and acetone leaf extracts have brought a significant mortality and desirable changes in biological life parameters of mosquitoes. High mortality in larval forms observed in methanolic leaf extract, followed by petroleum ether and least in acetone leaf extract which is in agreement with Singha *et al.* (2011), Halder *et al.* (2011), Nikkon *et al.* (2011), Choochote *et al.* (2004), Geris *et al.* (2012). Additionally, to support our work I want to state that, methanol leaf extracts of plant degrades rapidly being a plant product thereby reducing the possible accumulation of toxic residues in the environment, the same is stated by Mittal *et al.* (1995), furthermore WHO (2014) stated that the advantage of using methanolic extracts of plants can be a recommended larvicides rather than using chemical pesticides like malathion, rather than aqueous extract of plants. This further adds a consistent strong statement with those of other works of using solvent based extracts of plants.

According to Bowers *et al.* (1995) the screening of locally available medicinal plants for mosquito or vector control programme would generate employment to local people, and reduce the dependence on intense use of chemical pesticides and further stimulates the enhancement of public health in terms of physical and physiological aspects of biological pathways. Different plant parts contains complex of chemicals, but for the best part it is better to use tender leaf as stated by Govindarajan *et al.* (2008), due to its unique biological activity which is thought to be due to toxins and secondary metabolites which acts as mosquitocidal agents to in (Niraimathi *et al.*, 2010) integrated pest and vector management.

Voluminous plants bearing biological activities propose that plants are worth contemplation with all the control strategies involved in vector control programme in terms of feasibility (Kumar *et al.*, 2012), cost effectiveness and easy availability of plant resources. In our present study, acute toxicity against larval stages increased with increased in concentration of extracts and similar trend was observed by many plant based vector control workers with botanicals (Sakthivadivel and Daniel, 2008; Patil *et al.*, 2014; Kumar *et al.*, 2012; Pavela, 2007). When analyzing our obtained data against larval forms, at 1% and 2% concentration, the activity were more effective and maximal at 2% concentration itself. But when going through the research data by Rajkumar and Jabanesan, (2008), Martin Quintal *et al.* (2009), Kihampa *et al.* (2009), Kamaraj *et al.* (2010), Bagavan *et al.* (2009), there plants were exhibiting maximal activity against larval forms at 6%, 8%, 6%, 8%, 4% respectively against *Culex quinquefasciatus*. Pelah *et al.* (2002) stated that presence of carbohydrates, saponins, phytosterols, phenols, flavanoids and tannins in the plant extract having mosquito larvicidal activity in the botanicals.

Bansal *et al.* (2012) premeditated the methanolic leaf extract of *P. juliflora* and stated LC<sub>50</sub> values of 12 ppm against *Aedes aegypti* larvae. The mode of action and site of effect for larvicidal phytochemicals was not much described, but David *et al.* (2000) revealed the botanical derivatives principally affects the midgut epithelium and creates pores. The next principal effects is the gastric caeca and the malpighian tubules in the mosquito larvae is highly affect which leads to swelling and death of larval forms.

Our present investigation with the tested plant leaf extracts against all the larval, pupal and adult forms varied according to the solvent and concentration. The larval mortality, pupal mortality and adult mortality percentage increased with increase in extract concentration for the tested plant. These results agree to the extent of the previously mentioned suggestions of Sukumar *et al.* (1991), Ghosh *et al.* 2013 and Maurya *et al.* (2009). In the present study ethanolic leaf extracts was found to be effective larvicidal and pupicidal agent. Parallel observation was obtained in the studies on *Annona squamosa* extracts against *Culex* mosquito by Mehara and Haridhar (2000). Govindarajan (2009) evaluated the larvicidal and ovicidal properties of *Cassia fistula* against *Anopheles*, *Aedes* and *Culex* mosquitoes. Walmir *et al.* (2019) reported the isolation of a bioactive compound showing dextorotatory movement ((+) decentrine) from *Ocotea velozina* showing the larvicidal efficacy. Our results indicate the activity of *Salvia leucantha* having strong larvicidal, pupicidal, adulticidal and ovicidal activity which are comparable with the works of Modue and Nisber (2009) with *Azadirachtin*. Further characterization and isolation of bioactive molecules from the ethanolic leaf extracts of *Salvia leucantha* will provide clarity about the natures of these bioactive compounds. This can be an alternative to the conventional pesticides and insecticides which can be used to control *Culex quinquefasciatus*.

In the present study, there is a significant decrease in the percentage of larval and pupation and was found in the plant used in the study. Moreover, the pupation was found to depend of the plant type and the solvent system used for the extraction. Furthermore, the findings by us shows that the plant extracts were highly toxic to pupal forms, where 100% mortality was found in ethanolic leaf extract by using *Salvia leucantha* alone in the experimental level. In addition to the pupal effect, the percentage of emerging adults from

pupal forms from the treated larval forms also reduced. These result finding satisfies with Deepa *et al.* (2015), AI Dakhil and Morsy (1999) worked with neem (*Azadirachta indica*) leaf extract against *Culex pipens* larvae and Nathan *et al.* (2005) using methanolic leaf extracts and seeds of *Melia azedarach* against *Anopheles stephensi* larvae.

Exposure of *Culex quinquefasciatus* larvae to the sub-lethal dose of all the extracts of leaves from the present plant resulted in capricious effects according to the solvent and concentration of the extracts. Ethanol leaf extract significantly prolonged the larval duration of *Culex quinquefasciatus*. Moreover, plant observed to pupate slower than the control in the normal laboratory condition with increase in toxicity. Moreover the plant extracts significantly affected the larval and pupal developmental periods (Saxena *et al.*, 1993) and other researchers also showed prolongation of the larval and pupal developmental rate. Jeyabalan *et al.* (2003) used methanolic extract of *Pelargonium citrosa* leaf against *Anopheles stephensi* larvae, Nathan *et al.* (2005) by utilising the *Azadirachta indica* extract against *Anopheles stephensi* larvae, Nathan *et al.* (2006) using leaf and seed extracts by solvent methanol from chinaberry tree, *Melia azedarach* against *Anopheles stephensi* larvae and pupal mortality and duration. Sharma *et al.* (2006b) used petroleum ether leaf extracts of *Artemisia annua* against *Anopheles stephensi* and *Culex quinquefasciatus* larval and pupal forms on mortality and developmental duration. Using ethanolic leaf extract of *M. azedarach* against *Anopheles stephensi* and *Culex quinquefasciatus* by Coria *et al.* (2008), Juline *et al.* (2012) using *Moringa oleifera* against *Aedes aegypti* larval forms corresponds to our finding in extending the pupal and adult duration of *Salvia leucantha*.

Supavaran *et al.* (1974) enumerated the mode of action of crude plant extracts on *Culex quinquefasciatus* which is in agreement with our research findings with respect to concentration of extracts and solvents used in our study. When analysing the ovipositional activity against *Culex quinquefasciatus* with *Salvia leucantha* with solvent of ethanolic leaf extract showed highest deterrence activity. The findings of the present study are in agreement with earlier findings on the ovipositional deterrent effect of different plant origin. As observed ovipositional deterrence by Venkateswarlu *et al.* (1988) on neem oil and Ayyangar and Rao (1989) with methanol and acetone seed kernel extracts are not only larval repellents, but also a suitable ovipositional deterrent to the adult also. Raja *et al.* (2004) reported the ovipositional deterrent activities of *Coleus aromaticus* and *Aegle marmelos* extracts using n-hexane and methanol at 5% concentration. The oviposition activity in his study indicates that mosquitoes were acutely more sensitive and significant ovipositional deterrent occurring in response to different concentration of the extracts. Mosquitoes reject or select their specific hosts and oviposition by sensing chemicals signals that are detected by sensory receptors on the antennae (David *et al.*, 2000). In our study the comparable result may be due to receptor mediated response, which also compromises with Govindarajan *et al.* (2011) who observed that the leaf extract of *Azadirachta indica* with different solvents, viz., benzene, ethylacetate, chloroform and methanol had larvicidal, pupicidal, ovidical and ovipositional deterrence against mosquito. Where methanolic leaf extracts of *Azadirachta indica* proved the maximal efficacy similar to our observation in the present study. The mosquitocidal efficacy varied among the solvents, which compromises our research findings.

Further findings mosquito on ovipositional deterrent, ovidical and repellent activity by Elango *et al.* (2009) with indigenous plant extracts of *Andrographis lineate*, *Andrographis paniculata*, *Cocculus hirsutus*, *Eclipta prostrate* and *Tagetes erecta* have mosquitocidal activity, promoting the solvent extracts by Govindarajan *et al.* (2008b) with solvents methanol, benzene and acetone regarding the larvicidal, pupicidal, adulticidal, ovidical and repellent activities against *Aedes aegypti* and larvicidal and egg hatching inhibition properties of leaf extracts of *Coccinia indica* against *Culex* and *Aedes* mosquitoes, ovidical activities by Rajkumar and Jabanesan (2004) with *Solanum trilobatum* leaf extracts showed ovidical activity with egg rafts of *Culex quinquefasciatus* and *Culex tritaeniorhynchus*. All these author finding is in agreement with our finds that increase in concentration of extracts alters the normal biological activity and the ovipositional deterrence, ovidical and repellent activities varies based on type of solvent used among the plants. There is increase in ovipositional deterrence, repellency and egg hatching capacity among the treated groups, which is similar to their observation of Elango *et al.* (2009), Govindaraj *et al.* (2008), Rajkumar and Jabanesan (2004). Even our result agreed with respect to dose related response by the earlier reports by Dua *et al.* (2010) with *Culex quinquefasciatus*, the mortality of adult increased 100% with increase in concentration using methanolic leaf extract of *Lantana camara* followed by next intermediate activity by *Cassia occidentalis* with 93% and least in *Euphorbia hirta* of 81% of mortality of adults and increased ovipositional deterrence and adult repellency.

In the present investigation, all concentrations of plant extracts used exhibited repellency activity against *Culex quinquefasciatus* females. The present study also indicates that the ethanolic extractions were more effective in exhibiting a repellency action against the mosquito tested compared to control. Many plant extracts and essential oils of botanical origin manifest repellency activity against mosquitoes. The present observation is in accordance with the results of Sharma *et al.* (1993) against *Culex quinquefasciatus* of *Azadirachta indica*. Praveen *et al.* (2011) used ethanolic extracts of fruits of *Apium graveolens*; Prajapati *et al.* (2005) used the essential oil extracted from ten medicinal plants against *Culex mosquito*; Janeson and Katinka (2006) used ethyl acetate extracts of *Hyptis suaveolens* and Mansour *et al.* (1998) worked with ethanolic leaf extract of *Nigella sativa* seeds against *Culex* mosquitoes.

Repellents provide a mechanism for protecting ourselves from the bites of mosquitoes. The most preferred design for designing repellents is its long-lasting repellent activity, being of low toxicity to human and non-target organism, and being non-irritating. Extracts (ethanol) of the indigenous plant leaves against adult female mosquitoes indicted in our study signifies that the solvent used and the concentration of the extract plays an important role in the toxicity and repellency. In all the cases, in our study ethanolic leaf extracts showed higher repellency and with increase in concentration of the extracts.

In our observation, extracts of plant exerted mosquitocidal efficacy against *Culex quinquefasciatus*. Plant extracts used in our study *Salvia leucantha* acts as larvicidal, pupicidal, and adulticidal, growth and emergence inhibition, ovicidal, repellent and biting deterrent activities against the house hold mosquito carrier of filarial vector, *Culex quinquefasciatus*. Furthermore, our present finding leads to propose an alternative means of control of mosquitoes which are medicinally important pest and a means of replacement to synthetic insecticides. These botanical pesticides are often active against the target insects, less expensive, easily biodegradable in non-toxic form, environmentally safe and negligible change of bio-magnification, which have the potential to be used as mosquito control in the integrated vector management programme. Further studies on the tested plants including mode of action, synergism with the biocides under field control are needed. Save nature, save biosphere, save us.

## References

- Abbott, W.S. (1925) A method of computing the effectiveness of insecticides. *J. Am. Mosq. Control Assoc.*, **3(2)**:302 – 313.
- Alagarmalai Jeyasankar, Selvaraj Premalatha and Kuppusamy Elumalai (2012) Biological activities of *Solanum pseudocapsicum* (Solanaceae) against, cotton bollworm, *Helicoverpa armigera* Hubner and armyworm, *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae). *Asian Pac. J. Trop. Biomed.*, **5 (5)**: 1–5.
- Al-Dakhil, M.A. and Morsy, T.A. (1999) The larvicidal activities of the peel oils of three citrus fruits against *Culex pipiens*. *J. Egypt. Soc. Parasitol.*, **29 (2)**: 347 – 352.
- Anyaele, O.O, and Amusan, A.A.S. (2003) Toxicity of hexanoic extracts of *Dennettia tripetala* (G. Baxer) on larvae of *Aedes aegypti* (L.). *African Journal of Biomedical Research*. **6(1)**:49 – 53.
- Arivoli, S., John Ravindran, K. and Samuel Tennyson (2012) Larvicidal Efficacy of plant extracts against the malarial vector, *Anopheles stephensi* Liston (Diptera: Culicidae). *World J. Med. Sci.*, **7(2)**: 77– 80.
- Ayyangar, G.S.G, and Rao P.J. (1989) Neem (*Azadirachta indica*) extracts as larval repellents and ovipositional deterrents to *Spodoptera litura* (Fabr.). *Ind. J. Ent.*, **51(2)**: 121 – 124.
- Bagavan, A., Kamaraj, C., Abdul Rahuman, A., Elango, G., Abduz Zahir, A. and Pandiyan, G. (2009) Evaluation of larvicidal and nymphicidal potential of plant extracts against *Anopheles subpictus* Grassi. *Culex tritaeniorhynchus* Giles and *Aphis gossypii* Glover. *Parasitol. Res.*, **104(5)**: 1109 – 1117.
- Bansal, Singh, S.K., Karam, V., Sapna, and Sherwani (2012) Laboratory observations on the larvicidal efficacy of three plant species against mosquito vectors of malaria, Dengue/Dengue Hemorrhagic Fever (DF/DHF) and lymphatic filariasis in the semi-arid desert. *Journal of Environmental Biology*, **33(3)**: 617 – 621.
- Bavani Govindarajulu, A., Srimathi, Bhuvana, R. and Karthikeyan, J. (2015) Mosquito Larvicidal Efficacy of leaf extracts of *Annona reticulata* against *Aedes aegypti*. *Int.J.Curr.Microbiol.App.Sci.*, **4(8)**: 114 – 132.
- Becker, N., Petric, D., Boase, D., Lane, J., Zgomba, M., Dhal, C., and Kaiser, D. (2010) Mosquitoes and their control. 2<sup>nd</sup> edition. *Springler, Heidelberg, Germany*. 244 – 245.
- Bharati, M. and Saha, D. (2018) Multiple insecticide resistance mechanisms in primary dengue vector, *Aedes aegypti* (Linn.) from dengue endemic districts of sub-Himalayan West Bengal, India. *Plos One*, **13(9)**: 1 – 17.
- Bilal, A., Jahan, N., Ahmed, A., Bilal, S.N., Habib, S. and Hajra, S. (2012) Phytochemical and Pharmacological studies on *Ocimum basilicum* Linn - A Review. *I.J.C.R.R.*, **4 (23)**: 116 – 121.
- Bisset, J.A., Rodríguez, M.M., French, L., Severson, D.W., Gutiérrez, G., Hurtado, D. and Fuentes, I. (2014) Insecticide resistance and metabolic mechanisms involved in larval and adult stages of *Aedes aegypti* insecticide-resistant reference strains from Cuba. *J Am Mosq Cont Ass.*, **30(4)**: 298 – 304.
- Bowers, W.S., Sener, B., Evans, P.H., Bingol, F. and Erdogan, I. (1995) Activity of Turkish medicinal plants against mosquitoes *Aedes aegypti* and *Anopheles gambiae*. *Insect Sci Appl.*, **16(3)**: 339 – 342.
- Cetin, H. and Yani, A. (2006) Study of the larvicidal activity of *Origanum (Labiatae)* species from Southwest Turkey. *J. Vector Ecol.*, **31 (1)**: 118 – 122.
- Choochote, W., Tuetun, B. and Kanjanapothi, D. (2004) Potential of crude seed extract of celery, *Apium graveolens* L., against the mosquito *Aedes aegypti* (L.) (Diptera: Culicidae). *Journal of vector Ecology*, **29(2)**: 340 – 346.
- Corbet, S. A., Tiley, T., Moorhouse, C., Giam, S., Pursglove, J., Raby, J. and Rich, M. (2000) Surface films as mosquito larvicides: partitioning the mode of action. *Entomologia Experimentalis Et Applicata.*, **94(3)**: 295 – 307.
- Coria, C., Almiron, W., Valladares, G., Carpinella, C., Luduena, F., Defago, M. and Palacios, S. (2008) Larvicide and oviposition deterrent effects of fruit and leaf extracts from *Melia azedarach* L. on *Aedes aegypti* (L.) (Diptera: Culicidae). *Bioresource Technology*, **99(8)**: 3066 – 3070.
- David, J.P., Rey, D., Marigo, G. and Meyran, J.C. (2000) Differential toxicity of leaf litter to dipteran larvae of mosquito developmental sites. *J. Invertebr. Pathol.*, **75(1)**: 9 – 18.
- Deepa, J., Gokulraj, B. and Dhanasekaran. (2015) Larvicidal activity of Indian medicinal plants on dengue fever mosquito, *Aedes aegypti* Linnaeus. *Int. Journ. of Pure and App. Zool.* **3(2)**: 130 – 135.
- Dhar, R., Dawar, H., Garg, S., Basir, S.F. and Talwar, G.P. (1996) Effect of volatiles from neem and other natural products on gonotrophic cycle and oviposition of *Anopheles stephensi* and *Anopheles Culicifacies* (Diptera: Culicidae). *J Med Entomol.* **33(2)**: 195 – 201.
- Dias, C.N. and Moraes, D.F.C., (2014) Essential oils and their compounds as *Aedes aegypti* L. (Diptera: Culicidae) larvicide. *Parasitol Res.*, **113(2)**: 565 – 592.
- Dua, V.K., Pandey, A.C. and Dash, A.P. (2010) Adulticidal activity of essential oil of *Lantana camara* leaves against mosquitoes. *J. Am Mosq. Cont. Assoc.*, **24 (2)**: 309 – 315.
- Duncan, D.B. (1955) Multiple range and multiple 'F' tests. *Biometrics*, **11(1)**: 1 – 42.
- Elango, G., Rahuman, A.A., Bagavan, A., Kamaraj, C., Zahir, A.A. and Venkatesan, C. (2009) Laboratory study on larvicidal activity of indigenous plant extracts against *Anopheles subpictus* and *Culex tritaeniorhynchus*. *Parasitol Res.*, **104 (6)**: 1381 – 1388.

- Elizondo Quiroga, A., Flores Suarez, D., Elizondo Quiroga, G., Ponce Garcia, B. J., Blitvich, J. F., Contreras Cordero, J. I., Gonzalez Rojas, R., Mercado Hernandez, B. J. and Fernandez, S. (2006) Gonotrophic cycle and survivorship of *Culex quinquefasciatus* (Diptera : Culicidae) using sticky ovitraps in Monterrey, northeastern Mexico. *J. Am. Mosq. Control Assoc.* **22(1)**: 10 – 14.
- Farajollahi, A., Fonseca, D.M., Kramer, L.D. and Kilpatrick, A.M. (2011) Bird biting mosquitoes and human disease: a review of the role of *Culex pipiens* complex mosquitoes in epidemiology. *Infection, Genetics and Evolution*, **11(7)**: 1577 – 1585.
- Farajollahi, A., Healy, S. P., Unlu, I., Gaugler, R. and Fonseca, D. M. (2012) Effectiveness of Ultra-Low Volume Nighttime Applications of an Adulticide against Diurnal *Aedes albopictus*, a Critical Vector of Dengue and Chikungunya Viruses. *Plos One*, **7(11)**: 15 – 22.
- Foster, W. A. (1995) Mosquito sugar feeding and reproductive energetics. *Annu. Rev. Entomol.*, **40(2)**: 443 – 474.
- Geris, R., Ribeiro, P.R., Da Silva Brandao, M., Garcia Da Silva, H.H. and Garcia Da Silva, I. (2012) Bioactive natural products as potential candidates to control *Aedes aegypti*, the vector of dengue. *Studies natural products chemistry*, **37(1)**: 277 – 376.
- Ghosh, A., Chowdhury, N. and Chandra, G. (2013) Laboratory evaluation of a phytosteroid compound of mature leaves of day jasmine (Solanaceae: Solanales) against larvae of *Culex quinquefasciatus* (Diptera: Culicidae) and non-target organisms. *Parasitol. Res.*, **103(2)**: 221 – 277.
- Girdhar, G., Deval, K. and Mittal, P.K. (1988) Mosquito control by *Calotropis latex*, *J. Pesticides*, **15(2)**: 26 – 29.
- Govindarajan, M. (2009) Bioefficacy of *Cassia fistula* Linn. (Leguminosae) leaf extract against chikungunya vector, *Aedes aegypti* (Diptera: Culicidae). *Eur. Rev. Med. Pharmacol. Sci.*, **13(2)**: 99 – 103.
- Govindarajan, M., Jebanesan, A., Pushpanathan, T. and Samidurai, K. (2008) Studies on effect of *Acalypha indica* L. (Euphorbiaceae) leaf extracts on the malarial vector, *Anopheles stephensi* Liston (Diptera: Culicidae). *Parasitol. Res.*, **103(3)**: 691 – 695.
- Govindarajan, M., Jebanesan, A. and Pushpanathan, T. (2008b) Larvicidal and ovicidal activity of *Cassia fistula* Linn. leaf extract against filarial and malarial vector mosquitoes. *Parasitol. Res.*, **102(2)**: 289 – 292.
- Govindarajan, M., Mathivanan, T., Elumalai, K., Krishnappa, K. and Anandan, A. (2011) Ovicidal and repellent activities of botanical extracts against *Culex quinquefasciatus*, *Aedes aegypti* and *Anopheles stephensi* (Diptera: Culicidae). *Asian. Pac. J. Trop. Biomed.*, **1(1)**: 43 – 48.
- Grainge, M. and Ahmed, S. (1988) Handbook of Plants with Pest Control Properties. John Wiley and Sons, *New York*, **41**: 470 – 482.
- Gupta, G.K., Tejas Joshi., Keshu Madhudiya. and Arjit Chauduri. (2017) Therapeutic properties and nutritive values of some fruit bearing medicinal plants of Rajasthan state of India. *UK Journal of Pharmaceutical and Biosciences*, **5(5)**: 18 – 26.
- Haldar, K.M., Ghosh, P. and Chandra, G. (2011). "Evaluation of target specific larvicidal activity of the leaf extract of *Typhonium trilobatum* against *Culex quinquefasciatus* Say," *Asian Pacific Journal of Tropical Biomedicine*, **1(2)**: 199 – 203.
- Hamouda, L.S., Elyassaki, W.M. and Hamed, M.S. (1996) Toxicity and hisopathological effects of *Artemisia judaica* and *Anagallis arvensis* extracts on *C. pipiens* larvae. *J. Egypt. Ger. Soc. Zool.*, **20**: 43-60.
- Hauda Elfathi Osman, Awad Khalafalla Taha and Omer A.A. (2019) Larvicidal effects of three plant ethanolic extracts against *Culex quinquefasciatus* Say. Larvae (Diptera: Culicidae). *U. of K.J. Agri. Sci.* **19(3)**: 355 – 363.
- Janeson, G.T. and Katinka, P. (2006) Evaluation of extracts and oils of mosquito (Diptera: Culicidae) Repellent plants from Sweden and Guinea- Bissau. *Journal of Medical Entomology*. **43(1)**: 113 – 119.
- Jeyabalan, D., Arul, N. and Thangamathi, P. (2003) Studies on effects of *Pelargonium citrosa* leaf extracts on malarial vector, *A. stephensi* Liston. *Bioresour. Technol.*, **89(2)**: 185 – 189.
- Juline, E., Emmanuel Viana. P., Thiaga. H. and Ranilson, B. (2012). Effects of *Moringa oleifera* flower extract on larval trypsin and acetylcholinesterase activity in *Aedes aegypti*. *Arch. Of Insect Biochem. and Physi.* **79(3)**: 135 – 152
- Kamaraj, C., Bagavan, A., Rahuman, A.A., Zahir, A.A., Elango, G. and Pandian, G. (2009) Larvicidal potential of medicinal plant extracts against *Anopheles subpictus* Grassi and *Culex tritaeniorhynchus* Giles (Diptera: Culicidae). *Parasitol. Res.*, **104(5)**: 1163 – 1171.
- Kamaraj, C., Rahuman, A.A., Bagavan, A., Abduz Zahir, A., Elango, G. and Kandam, P. (2010) Larvicidal efficacy of medicinal plant extracts against *Anopheles stephensi* and *Culex quinquefasciatus* (Diptera: Culicidae). *Trop. Biomed.*, **27(2)**: 211 – 219.
- Kannathasan, K., Senthilkumar, A., Chandrasekaran, M. and Venkatesalu, V. (2007) Differential larvicidal efficacy of four species of *Vitex* against *Culex quinquefasciatus* larvae. *Parasitol Res.*, **101(6)**: 1721 – 1725.
- Katz, T. M., Miller, J. H. and Hebert, A. A. (2008) Insect repellents: Historical perspectives and new developments. *J. Am. Acad. Dermatol.* **58(2)**: 865 – 871.
- Kihampa, C., Joseph, C.C., Nkunya, M.H., Magesa, S.M., Hassanali, A. and Heydenreich, M. (2009) Larvicidal and IGR activity of extract of Tanzanian plants against malaria vector mosquitoes. *J Vector Borne Dis.*, **46(4)**: 145 – 152.
- Kumar, G., Karthik, L., Rao, K.V.B., Kirthi, A.V. and Rahuman, A.A. (2012) Larvicidal, repellent and ovicidal activity of *Calotropis gigantea* against *Culex gelidus* and *Culex tritaeniorhynchus* (Diptera: Culicidae). *Journal of Agricultural Technology*, **8(3)**: 869 – 880.
- Mansour, M.A., Ginwai, O.T., El Hadiya, A.S., El Khatib, O.A., Al-Shabanah, H.A. and Al Sawaf. (1998) Effects of volatile oil constituents of *Nigella sativa* on carbon tetrachloride-induced hepatotoxicity in mice: evidence for antioxidant effects of thymoquinone. *Res. Commun. Mol. Pathol. Pharmacol.*, **110(5)**: 239– 251.
- Martin-Quintal, Z., Moo-Puc, R., Gonzalez-Salazar, F., Chan-Bacab, M.J., Torres-Tapia, L.W. and Peraza-Sanchez, S.R. (2009) *In vitro* activity of *Tridax procumbens* against promastigotes of *Leishmania Mexicana*. *J. Ethnopharmacol.*, **122**: 463 – 477.
- Maurya, P., Sharma, P., Mohan, L., Batabyal L. and Srivastava, C.N. (2009) Evaluation of the toxicity of different phytoextracts of *Ocimum basilicum* against *Anopheles stephensi* and *Culex quinquefasciatus*. *Journal of Asia-Pacific Entomology*, **12(2)**: 113 – 115.
- Mehra, B.K. and Hiradhar, P.K. (2000) Effect of crude acetone extract of seeds of *Annona squamosa* Linn. (Family: Annonaceae) on possible control potential against larvae of *Culex quinquefasciatus* Say. *J. Entomol. Res.*, **24(2)**: 141– 146.

- Merritt, R. W., Dadd, R. H. and Walker, E. D. (1992) Feeding-behavior, natural food, and nutritional relationships of larval mosquitos. *Annu. Rev. Entomol.* **37(1)**: 349 – 376.
- Miller, B.R., Crabtree, M.B. and Savage, H.M. (1997) Phylogenetic relationships of the Culicomorpha inferred from 18S and 5.8 S ribosomal DNA sequences (Diptera: Nematocera). *Insect molecular Biology*, **6(2)**:105 – 114.
- Mittal, P.K., Adak, T. and Sharma, V.P. (1995) Bioefficacy of six neem (*Azadirachta indica*) products against mosquito larvae. *Pesticide Research Journal*, **7(1)**: 35 – 39.
- Modue and Nisber (2009) Vector competence of Australian mosquitoes (Diptera: Culicidae) for Japanese encephalitis virus. *J. Med. Entomol.*, **40 (1)**: 82 – 90.
- Murugan, K. and Jeyabalan, D. (1999) Mosquitocidal effect of certain plant extracts on *Anopheles stephensi*, *Curr. Science*, **76(5)**: 631 – 633.
- Murugan, K., Babu, T.S., Jeyabalan, D., Senthil Kumar, N. and Sivaramkrishnan, S. (1996) Antipupational effect of neem oil and neem seed kernel extract against mosquito larvae of *An. stephensi* (Liston). *J. Entomol. Res.*, **20(1)**: 137 – 139.
- Murugan, K., Mahesh, K.P. and Kovendan, K. (2012) Larvicidal, pupicidal, repellent and adulticidal activity of *Citrus sinensis* orange peel extract against *Anopheles stephensi*, *Aedes aegypti* and *Culex quinquefasciatus* (Diptera: Culicidae). *Parasitol Res.*, **111(4)**: 1757 – 1769.
- Murugan, K., Murugan, P. and Noortheen, A. (2007) Larvicidal and repellent potential of *Albizia amara* Boivin and *Ocimum basilicum* L. against dengue vector, *Aedes Aegypti* (Insecta: Diptera: Culicidae). *Biores. Technol.*, **98(1)**: 198 – 201.
- Murugan, K., Thangamathi, P. and Jeyabalan, D. (2003) Interactive effect of botanicals and *Bacillusthuringiensis subsp. israelensis* on *Culex quinquefasciatus* say. *J. Sci. Indus. Res.*, **61(12)**:1068 – 1076.
- Muthukrishnan, J., Pushpalatha, E. and Kasthuribhai, A. (1997) Biological effects of four plant extracts on *Culex quinquefasciatus* larval stages. *Insect Sci. Appl.*, **17(3)**: 389 – 394.
- Nathan, S.S., Chung, P.G. and Murugan, K. (2006) Combined effect of biopesticides on the digestive enzymatic profiles of *Cnaphalocrocis medinalis* (Guenee) (the rice leaf folder) (Insecta: Lepidoptera: Pyralidae). *Ecotoxicol. Environ. Saf.*, **64(3)**: 82 – 89.
- Nathan, S.S., Kalaivani, K. and Murugan, K. (2005) Effects of neem limonoids on the occurring in *Achillea millefolium* L. (Asteraceae). *Economic Botany*, **48(3)**: 111 – 120.
- Nikkon, F., Habib, M.R., Saud, Z.A and Karim, M.R. (2011). “*Tagetes erecta* Linn. And its mosquitocidal potency against *Culex quinquefasciatus*,” *Asian Pacific Journal Of Tropical Biomedicine*, **1(3)**: 186 – 188.
- Niraimathi, S., Balaji, N., Venkataramanan, N. and Govindarajan, M. (2010). Larvicidal activity of alkaloid from *Sida acuta* against *Anopheles subpictus* and *Culex tritaeniorhynchus*. *Int J Curr Res.*, **11**:34 – 38.
- NVBDCP (2018) National Vector Borne Disease Control Programme. Filariasis: Magnitude of disease. *NVBDCP*, 226 – 268.
- Okumu, F. O., Killeen, G. F., Ogoma, S., Biswaro, L., Smallegange, R.C., Mbeyela, E., Titus, E., Munk, C., Ngonyani, H., Takken, W., Mshinda, H., Mukabana, W. R. and Moore, S.J. (2010) Development and Field Evaluation of a Synthetic Mosquito Lure That Is More Attractive than Humans. *Plos One* **5(1)**: 7 – 13.
- Okumu, F., Knols, B.G.J. and Fillinger, U. (2007) Larvicidal effects of a neem (*Azadirachta indica*) oil formulation on the malaria vector *Anopheles gambiae*. *Malaria J.*, **6(1)**: 63 – 69.
- Ouda, N.A.A., Al-chalabi, B.B.M., Al-charchafchi, F.F.M.R. and Mohsen, Z.Z.H. (1998) Extract of *Atriplex canescens* against *Culex quinquefasciatus*. *Pharm Biol.*, **36(1)**: 69 – 71.
- Patil, P. B., Kallapur S. V., Kallapur, V.L. and Holihosur, S. N. (2014) *Clerodendron inerme* : Plant as an effective natural product against dengue and filarial vector mosquitoes. *Asian Pacific Journal of Tropical Disease*, **4(1)**: 453 – 462.
- Pavela, R. (2007) Possibilities of botanical insecticides exploitation in plant protection, *Pest Tech*, **1(1)**: 47 – 52.
- Pawlowski, J., Szadziewski, R., Kmiecik, D., Fahrni, J. and Bittar, G. (1996) Phylogeny of the infraorder Culicomorpha (Diptera: Nematocera) based on 28S RNA gene sequences. *Systematic Entomology*. **21(2)**: 167 – 178.
- Pelah, D., Abramovich, Z., Markus, A. and Wiesman, Z. (2002) The use of commercial saponin from *Quillaia saponaria* bark as a natural larvicidal agent against *Aedes aegypti* and *Culex pipiens*. *J. Ethnopharmacol.*, **81(3)**:407 – 409.
- Prajapati, V., Tripathi, A.K., Agarwal, K.K. and Khanuja, S.P. (2005) Insecticidal, repellent and oviposition deterrent activity of selected essential oils against *Anopheles stephensi*, *Aedes aegypti* and *Culex quinquefasciatus*. *Bioresour Technol.*, **96(16)**: 1749 – 1757.
- Praveen, N., Atequque, A., Sun, K. and Min, C. (2011) Chemical composition, antioxidant activity and larvicidal effects of essential oil from leaves of *Apium graveolens*. *Immunopharmacology and Immunotoxicology*. **34(2)**: 205 – 209.
- Priyanka Rai, Minu Bharati, Abhisekh Subba and Dhiraj Saha (2019) Insecticide resistance mapping in the vector of lymphatic filariasis, *Culex quinquefasciatus* Say from northern region of West Bengal, India. *Plos One*, **14(5)**: 1 – 17.
- Rahuman, A.A. and Venkatesan, P. (2008) Larvicidal efficacy of five cucurbitaceous plant leaf extracts against mosquito species. *Parasitol. Res.*, **103(1)**: 133 – 139.
- Raja, N., Jayakumar, M., Elumalai, K., Jeyasankar, A., Muthu, C. and Ignacimuthu, S. (2004) Oviposition deterrent and ovicidal activity of solvent extracts of 50 plants against armyworm *Spodoptera litura*, Fab. (Lepidoptera: Noctuidae). *Malaysian Applied Biology Journal*. **33(2)**: 73 – 81.
- Rajkumar, S. and Jebanesan, A. (2004) Ovicidal activity of *Solanum trilobatum* L. (Solanaceae) leaf extract against *Culex quinquefasciatus* Say and *Culex tritaeniorhynchus* Giles (Diptera: Culicidae). *Int. J. Trop. Insect Sci.*, **24 (4)**: 340 – 342.
- Rajkumar, S. and Jebanesan, A. (2008) Bioactivity of *Chenopodium ambrosioides* L. (Family: Chenopodiaceae) against the filariasis vector *Culex quinquefasciatus* Say (Diptera: Culicidae). *Canadian. J. Pure. Appl. Sci.*, **16 (1)**: 129 – 133.
- Reisen, W. K. (2012) The contrasting bionomic of *Culex* mosquitoes in western North America. *J. Am. Mosq. Control Assoc.*, **28(4S)**: 82 – 91.
- Reiter, P. (1983) A portable, battery-powered trap for collecting gravid *Culex* mosquitos. *Mosquito News*, **43(4)**: 496 – 498.
- Roberts, D., and M. Kokkinn. (2010) Larval crowding effects on the mosquito *Culex quinquefasciatus*: physical or chemical? *Entomologia Experimentalis Et Applicata.*, **135(3)**: 271 – 275.

- Rose, R. I. (2001) Pesticides and public health: Integrated methods of mosquito management. *Emerging Infectious Diseases*, **7**(1): 17 – 23.
- Rueda, L. M., K. J. Patel, R. C. Axtell, and R. E. Stinner. (1990). Temperature-dependent development and survival rates of *Culex quinquefasciatus* and *Aedes aegypti* (Diptera, Culicidae). *J. Med. Entomol.* **27**(5): 892 – 898.
- Russell, T.L., Kay, B.H. and Skilleter, G.A. (2009) Environmental effects of mosquito insecticides on saltmarsh invertebrate fauna. *Aquat. Biol.* **6**(1): 77 – 90.
- Sakthivadivel, M. and Daniel, T. (2008) Evaluation of certain insecticidal plants for the control of vector mosquitoes viz. *Culex quinquefasciatus*, *Anopheles stephensi* and *Aedes aegypti*. *Appl. Entomol. Zool.*, **43**(1): 57 – 63.
- Saxena, R.C., Dixit, O.P. and Sukumaran, P. (1992) Laboratory assessment of indigenous plant extracts for anti-juvenile hormone activity in *Culex quinquefasciatus*. *Indian J. Med. Res.*, **95**(2): 199 – 204.
- Sharma, P., Mohan, L. and Srivastava, C.N. (2006b) Growth inhibitory nature of *Artemisia annua* extract against *Culex quinquefasciatus* Say. *J Asia Pacific Entomol.* **9**(1): 389 – 395.
- Sharma, R.N., Gupta, A.S., Patwardhan, S.A., Hebbalkar, D.S., Tare, V. and Bhonde, S.B. (1992) Bioactivity of lamiaceae plants against insects. *Indian. J. Exp. Biol.*, **30**(1): 244 – 246.
- Sharma, V.P., Ansari, M.A. and Razdan, R.K. (1993) Mosquito repellent action of neem (*Azadirachta indica*) oil. *J. Am. Mosq. Control. Assoc.*, **9**(3): 359 – 363.
- Singh, S.P., Raghavendra, K., Singh, P.K. and Subbarao. S.K. (2001) Studies on larvicidal property of leaf extracts of *Solanum nigrum* (Family: Solanaceae). *Current Science.*, **81**(12): 1529 – 1530.
- Singha, S., Adhikari, U. and Chandra, G. (2011) Smoke repellency and mosquito larvicidal potentiality of *Mesua ferra* L. leaf extracts against filarial vector *Culex quinquefasciatus* Say. *Asian Pacific Journal of Tropical Biomedicine*, **1**(1): 119 – 123.
- Sukumar, K., Perich, M.J. and Boobar, L.R. (1991) Botanical derivatives in mosquito control: a review. *J. Am. Mosq. Control. Assoc.*, **7**(2): 210 – 237.
- Supavaran, P., Fred, W.K.I. and Roy, S. (1974) Phytochemical extracts for control of mosquito larvae. *J. of the American Mosq. Con. Ass.*, **7**(2): 404 – 408.
- Thambusamy Pushpanathan, Arulsamy Jebanesan and Marimuthu Govindarajan (2008) The essential oil of *Zingiber officinalis* Linn (Zingiberaceae) as a mosquito larvicidal and repellent agent against the filarial vector *Culex quinquefasciatus* Say (Diptera: Culicidae) *Parasitology Research*, **102**(6): 1289 – 1291.
- Vatandoost, H. and Vaziri, V.M. (2004) Larvicidal activity of a neem tree extract (Neemarin) against mosquito larvae in the Islamic Republic of Iran. *East Mediterr. Health, J.*, **10**(4): 573 – 581.
- Venkatachalam, M.R. and Jebanesan, A. (2001) Repellent activity of *Ferronia elephantum* Corr. (Rutaceae) leaf extract against *Aedes aegypti*. *Bioresour. Technol.*, **76** (3): 287 – 288.
- Venkateswarlu, P., Raghavaiah, G. and Nagalingam, B. (1988) Effect of neem oil on certain behavioural aspects of *Spodoptera litura* Fabricius in urdbean. *Ind. J. of Innovative Sciecn and Res. Tech.*, **2**(4): 118 – 123.
- Walmir Silva Garcez, Carolina da Silva Barbosa, Ligia Miranda Ferreira Borges, Jose Nicacio, Reginaldo Dias Alve, Carlos Henrique Miguita, Ivana Maria Povoá Violante, Lidilhone Hamerski and Fernanda Rodrigues Garcez (2009) In vitro activities of plant extracts from Brazil against vectors. *Exp. Appl. Acarol.*, **60**: 421 – 430.
- WHO (1996) Report of the WHO informal consultation on the evaluation and testing of insecticides. *WHO, Geneva*, 36 – 52.
- WHO (2014) A global brief on vector-borne diseases. Geneva, Switzerland, 442 – 461.
- Wilkerson, R.C., Linton, Y.M., Fonseca, D.M., Schultz, T.R., Price, D.C. and Strickman, D.A. (2015) Making mosquito taxonomy useful: a stable classification of tribe Aedini that balances utility with current knowledge of evolutionary relationships. *Plos one*, **10**(7): 17 – 26.