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Review on Potential Eco-friendly Biolarvicides against Dengue Vector: *Aedes aegypti* (Linn) (Diptera: Culicidae)

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Abstract: **Mosquito species serves as a vector for the transmission of various diseases to human beings. One of these species, *Aedes aegypti* acts as a vector source for the spread of viral disease dengue fever. Presently numerous chemi-insecticides and repellants are available which are commonly used as a preventive measure. But, use of these insecticides poses various other ill-effects which includes allergies like skin itching, encephalopathy skin eruption, respiratory disorders as well as harmful to environment. So overcome these adverse effects due to synthetic mosquitocides. There is a need to develop repellants and mosquito larvicidal from botanical origin. They are target specific, biodegradable, cheap, easily available and ecofriend to our environment.**

The aim of present review is to shower light on biolarvicides to control vector Aedes aegypti from currently available research literature. For this purpose, original research articles from major databases were studied. Our literature review show that 212 essential oils from 145 plant species belonging to 54 families which had been tested for larvicidal property against *Aedes aegypti*. These biolarvicides were extracted using various techniques and 19 different solvents. Out of these, 57 extracts of essential oils shows LC50 values less than 100ppm, 17 extracts shows LC50 values of less than 100mg/lit and 42 extracts has LC50 values less than 100 µg/ml. Biolarvicides are safe, effective, target specific, biodegradable and eco-friendly in nature. These should be promoted more to control vector species.

***Keywords: Aedes aegypti*, biolarvicides, LC50 and dengue fever.**

1. INTRODUCTION

Dengue emerged in the second half of the twentieth century as a major public health concern in many tropical and sub-tropical regions around the world.(WHO, 2009)[67]. It is currently the most important mosquito-borne, human viral disease. Dengue fever viruses (DENV) are positive stranded RNA virus of the family Flaviviridae and genus Flavivirus [73]. Dengue is a self limiting acute mosquito transmitted disease characterized by fever, headache, muscle, joint pains, rash , nausea and vomiting. As Dengue Fever (DF) is spread by *Aedes* mosquitoes, it is also referred as arboviral disease. Some infections result in Dengue Hemorrhagic Fever (DHF) and in its severe form Dengue Shock Syndrome (DSS) can threaten the patient`s life [76]. Dengue illnesses are caused by any of the four serologically related viruses designated as DENV-1, DENV-2, DENV-3 and DENV-4[74].Till now, dengue fever was believed to be caused by these four different serotypes. The discovery of fifth variant DENV-5 has been isolated in October 2013 from Sirawak city in Malaysia. This serotype follows the sylvatic cycle unlike the other four serotypes which follow the human cycle. There is no indication of the presence of DENV-5 in India [75].

1.1 Global Scenario of Dengue:

The incidence of dengue has grown dramatically around the world in recent decades. The actual numbers of dengue cases are under reported and many cases are misclassified. The published data and cases of Dengue Fever are reported only from cases registered in government hospitals and not from private hospitalized cases (Various Newspaper articles). An estimated 40% of the global population (~3.9 billion) is at risk of dengue virus (DENV) infection [77,78, 89]. About 2.5% of people affected with severe dengue die each year [79]. One recent estimate indicates 390 million dengue infections per year 95% credible interval 284–528 million, of which 96 million (67–136 million) manifest clinically (with any severity of disease) [68]. Another study, of the prevalence of dengue, estimates that 3.9 billion people, in 128 countries, are at risk of infection with dengue viruses [69]. The disease is endemic in more than 125 countries and the spread to newer areas is mainly attributed to returning travelers from endemic countries [80, 81]. Overall research indicates that dengue spread its boundary and burden day by day since last decades.

1.2 Indian Scenario of Dengue:

The resurgence of dengue poses a major challenge as all the four serotypes of dengue have been reported from various parts of India [82]. The resurgence of DF in the country can be attributed to rapid development and economic expansion which not only led to urbanization but also increased movement of people between cities and states. In India, every year cases are spreading to newer geographical areas [NVBDCP- annual report: 2014-15]. Recently the dengue expands its boundary even in rural parts of India.

1.3 Epidemiology Situation in India during last decade:

During 2006-2008, 18 States and Union Territories (UTs) reported dengue cases. The number increased to 20 and 29 during 2009 and 2010 respectively. In 2010 total 28292 cases and 110 deaths have been reported. During 2012, 50222 cases and 242 deaths and during 2013, 75808 cases and 193 deaths were reported. Highest number of deaths were reported by Maharashtra (48) followed by Kerala (29) and Punjab (25). Up to November, 2014, 33320 cases and 86 deaths have been reported in Annexure-5[Information source: NVBDCP].

India serves 6-9% of total cases in South-East Asian Region (SEAR) countries between 2009 and 2011, which has increased to 19% in 2013[83]. Now Dengue is endemic in all States and UTs of India .According to the National Vector Borne Disease Control Programme [NVBDCP] data, the worst affected areas in India in 2015 were Delhi, Punjab, Haryana, Gujarat, Karnataka and Kerala with a range of about 4000–15,000 cases and 9–60 deaths [85] and also a total of 99,913 dengue cases and 220 deaths were reported from 35 States/UTs areas during 2015. Recurring outbreaks of dengue have been reported from Andhra Pradesh, Delhi and Goa. Over the years [70]. During 2016: 1, 29,166 dengue cases and 245 deaths were reported whereas in 2017: number of dengue cases rises to 1, 53,635 and 226 deaths[Data source: NVBDCP,India].

A recent review has reported that India alone contributes to 34 %(about 33 million infections) of the total global threat of dengue leading to hyper-endemicity, prevailing mostly in urban areas [84]. However, the wide spread problem of underreporting of dengue cases from India has come into focus very recently and the real burden of dengue in the country is heavily ignored [86, 87]. The annual number of dengue fever cases in India is many times higher than it is officially reported [88]. A recent study reports that an average of six million people a year in India had a symptomatic illness between 2006 and 2012 with dengue [86].

1.4 Factors contributing to the spread of Dengue in India:

Risk of dengue and geographical spread of Dengue has shown an increase in recent years due to various factors in urban, sub-urban and rural areas, leading to proliferation of mosquito breeding sites. These include: rapid and unplanned urbanization; population growth; increasing inadequate municipal services; increased use of non-biodegradable products (bottles, plastic, cans, tyres) and also an unaccustomed growth in the population movement and commodities via travel and commerce[NVBDCP,90].

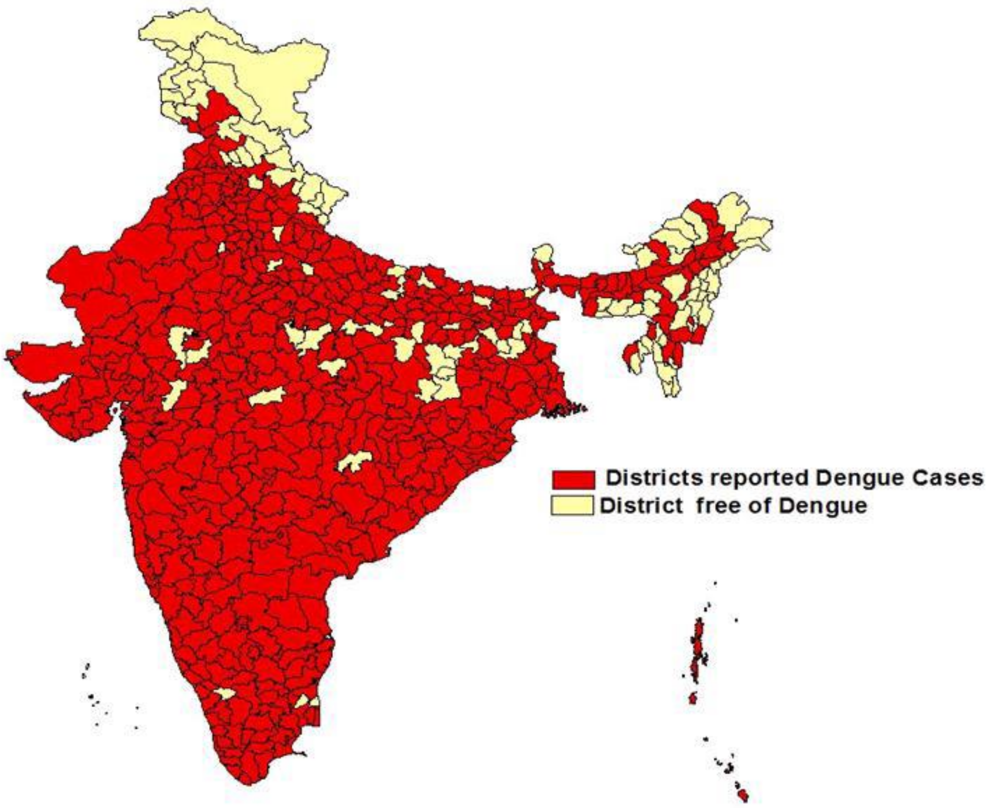
In India, *Ae. aegypti* is the main vector in most urban areas; however, *Ae. Albopictus* is also found as vector in few areas of Southern and Eastern India. *Ae. aegypti* mosquito breeds mostly in manmade containers, whereas, *Ae. Albopictus* breeds mainly in natural larval habitats like tree holes, leaf axils and coconut shells etc. Unlike other mosquitoes, it is a daytime feeder; its peak biting activity is in the morning and in the evening before dusk [Who, India, NVBDCP -2015

(91)]. The population of *Ae. aegypti* fluctuates with rainfall and humidity [67,89]. Under optimal conditions the life cycle of aquatic stage of the *Ae. aegypti* - the time taken from hatching to adult emergence is seven days in optimal condition (temperature 25±50C and relative humidity 70-80%).

- ❖ Higher temperature favors larval development and rate of emergence of adult mosquito.
- ❖ Higher rainfall increases the number of flooded breeding sites and Lower rainfall prompts people to store water – mosquitoes use these containers as breeding sites.
- ❖ Humidity influences mosquito lifespan and in turn the potential for virus transmission will be greater [90]. *Aedes* can fly up to a limited distance of 400 meters [91].

The rural spread of *Aedes* is associated with expanding network of rural water supply schemes and other development projects without health impact assessments, scarcity of water with consequent water storage, changing lifestyle with improper use of desert coolers and indiscriminate use of disposable containers, bottles, etc. and improved transport system and population movement.[95, 96, 97]

1.5 Dengue affected areas since 1991



2. VECTOR CONTROL METHODS

Vector control is known to be a good method for prevention of vector borne diseases. It is said that, Vectors May Be A Threat to You At Home And When Travelling."At present, stopping of invasion of Aedes transmitting mosquitoes is the only method to prevent or control dengue virus [90]. A range of *Aedes* control methods now exists.

- ❖ Environmental sanitation measures to reduce mosquito breeding sites, such as physical management of water containers (e.g. mosquito-proof covers for water storage containers, polystyrene beads in water tanks), better designed and reliable water supplies, and recycling of solid waste such as discarded tyres, bottles, and cans.[92,93,94]
- ❖ Biological methods (e.g. fish, Copepods – small crustaceans that feed on mosquito larvae) to kill or reduce larval mosquito populations in water containers.[98]

- Chemical methods against the mosquito's aquatic stages for use in larger water containers (e.g. Temephos) [98].
- Chemical methods directed against adult mosquitoes, such as insecticidal sprays (98).
- Personal protection through use of repellents, vaporizers, mosquito coils, and insecticide treated screens, curtains, and bed nets during daytime against *Aedes* [98].

The evolution and spread of resistance to insecticides is a major concern for the control of dengue vector. Bioassay data demonstrate that resistance to organophosphates (Temephos) and pyrethroids is widespread in *Ae. aegypti* and resistance has also been reported in Ae. albopictus [79,WHO,2012-2020] so the ultimate method left to control larval mosquito species is use of essential oils of plant origin as mosquito biolarvicide [97]. These essential oils are effective as ovicidal, larvicidal, oviposition deterrant, repellant, adulticidal activities against vector mosquito species. It contents a bioactive component from indigenous source which help us in vector control.[99]

2.1 Meaning of Biolarvicide:

Biolarvicides are plant derived essential oils extracted from diverse plant species using various solvents and tested for its potential as to kill immature stages of mosquito larvae.

2.2 Benefits of Essential Oils:

Essential oils are volatile aromatic liquids created by plants to help them maintain their own health and vitality. Essential oils have been used by mankind for thousands of years to help enhance physical, mental, emotional, and spiritual health. Science has only recently begun to unfold how these precious liquids, and the chemical compounds they contain, can work to affect the body and mind [71].

2.3 Industrial Uses of Essential Oils:

Essential oils have a significant role in the society where they are variously used in fields such as medicine, pharmacy, cosmetics, chemical and food-processing industries [70]. All pure essential oils have some anti-bacterial properties. They increase the production of white blood cells, which helps to fight against infectious illnesses. It is through these properties that aromatic herbs have been esteemed so highly throughout the ages and so widely used during the onsets of malaria, typhoid, and also during, the epidemic plagues during the 16th century. Research has found that people who consistently use pure essential oils have a higher level of resistance to illnesses, colds, flues, and diseases than the average person [71]. The bioactive components in essential oils also possess the antiviral, antifungal and antilarval activities.

2.4 Biolarvicidal Plant parts:

Though each part of plant possess some kind of larvicidal activity due to presence of alkaloids, flavonoids, terpenes, fatty acids, hydrocarbons ,steroids, saponins compounds. However, choice of plant part is most important. During study, it was observed that seeds and fruits of species show more lethality than leaves. In *Calophyllum inophyllum*, the LC50 values of seeds and leaves extract are 8.2mg/ml and 35 mg/ml respectively [56]. In *Rhizophora mucronata, Rhizophora apiculata, and Bruguiera cylindrica*, the LC50 values in the extracts of stiltroot, bark, hypocotyl, collar, leaf shows increase trend in ethanolic extracts [51].

The various plant parts in review includes leaves ,seeds , fruits, flowers, rhizome, stem , bark, wood, roots, whole plants, hypocotyls, collar, bud, berry. Here in, we had most data on leaves (91) followed by seeds (16) and whole plants (09).

2.5 Choice of solvent for extraction of Biolarvicide product:

It is also one of the most important part of consideration. As proper choice of solvent is must to get efficient results of larvicidal activity of mosquito larvae under study. Bioactive component of interest must get extracted in solvent selected [122]. Based on polarity of solvent, the solvents used for extraction can be categorized as follows:

(1) Non Polar solvent : It includes hexane, benzene, petroleum ether, diethyl ether

(2) Polar solvent: It includes methanol, ethanol, propanol, butanol, ethyl acetate, acetone . Most preferred polar solvent includes ethanol followed by methanol while in non- polar solvents, preferred choice is hexane followed by petroleum ether.

Hence, the choice of solvent is very important as phytochemicals show differing miscibility of bioactive component in different solvents and in turn shows differing range of activity of extract. For instance, the leaf extracts of *Alternanthera sessilis* in butanol, propanol, ethanol, hexane shows LC50 values of 54.79 mg/ml, 75.94 mg/ml, 91.17 mg/ml, 163.81 mg/ml indicates an increase in LC50 values from polar to non polar solvent. In contrast to this, *Amarnthus dubius* show decrease in LC50 values from polar to non polar solvent [20]

2.6 Essential oils as biolarvicide:

The aim of research focused on seeking new essential oils that could become suitable active substances for new botanical larvicidal, thereby providing an eco-friendly substitute over some risky synthetic insecticides.[100].

The purpose of this review is to evaluate the current biological efficacy of plant parts extracts as larvicidal against dengue fever vector *Aedes aegypti*. It includes articles selected from available literature which covers 145 plant species belonging to 54 families. These biolarvicides were extracted using various methods and 19 different solvents and assessment was done with the criteria of efficacy of extracts as biolarvicidal and having LC50 values less than either100ppm.(100mg/L or 100 µg/ml, 10 mg/ml)

Table 1: This table gives the summary about diversity of plant species showing larvicidal activity against larval instars of Aedes aegypti. It also highlights the information of the plant part used, Stage of larval instars, solvent used for extraction of essential oils (biolarvicidal product), values of lethal concentration of extract which causes 50% and 90% mortality in larvae i.e. LC50 and LC90 values after 24 hours of exposure of larvae to concentration gradient.

Table 1

Family &Scientific Name of species	(Common Name)	Larval instar used for bioassay	Plant Parts Used	Solvent used for extraction of essential oil	LC50 Value	LC90 Value	Ref No
Family:-Acanthaceae							
Rhinocanthus nasutus	Snake Jasmine	Late III and early IV	Roots	75% alcohol	16.04mg/Lit	47.08mg/Lit	1
Andrographis paniculata(Burm.F)	King of Bitters	I	Leaf	Acetone	113.661ppm	247.062 ppm	46
		II			149.068 ppm	268.120ppm	
		III			162.731 ppm	309.342ppm	
		IV			216.888ppm	389.015ppm	
B.maderaspatensis	Hajarmani	IV	Leaf	Ethyl acetate	197.6 ppm	438.0 ppm	13
Family:-Acoraceae							
Acorus calamus	Sweet sage	III+IV instar	Rhizome	Ethyl alcohol	64.22mg/L	130.37 mg/L	4
				Petroleum ether	57.32 mg/L	120.13 mg/L	
Family:-Amaranthaceae							
Alternanthera sessilis	Sessile Joyweed	III	Leaf	Hexane	163.81 mg/L	394.69 mg/L	20
				Butanol	54.79 mg/L	130.79 mg/L	
				Propanol	75.94 mg/L	187.87 mg/L	
				Ethanol	91.17 mg/L	206.71 mg/L	
Amaranthus dubius	Spleen amaranth	III	Leaf	Hexane	161.21 mg/L	408.93 mg/L	20
				Butanol	320.94 mg/L	891.73 mg/L	
				Propanol	249.21 mg/L	790.65 mg/L	
				Ethanol	130.37 mg/L	321.88 mg/L	
Achranthes aspera	Pricklychaff flower	Early IV	Stem	Hexane	57.50 ppm	90.84 ppm	28

Celosia argentia	Plumed cockscomb	Early III	Leaf	Ethanol	134.4 ppm	-	41
Family:-Amaryllidaceae							
Allium sativum	Garlic	Early IV	Stem	Hexane	218.35 ppm	434.76 ppm	28
Apium graveolens	Onion	IV	Seeds	Methanol	LC100= 50 µg/ml		5
Family:-Anacardiaceae							
Magnifera indica	Mango	III	Leaves	Methanol	630.39 ppm	LC95=779.08ppm	24
Family:-Annonaceae							
Annona squamosa	Custard apple	Larvae IV inst.	Leaf	Acetone	190.5 ppm	323.6 ppm	3
Annona muricata	Sour Sop		Root	Ethanol	42.3 µg/ml	200 µg/ml	15
Annona crassiflora	Marolo		Root wood	Ethanol	0.71µg/ml	5.12µg/ml	
Annona glabra	Pond apple		Seed	Ethanol	0.06µg/ml	2.75 µg/ml	
Family:-Asteraceae							
Eclipta alba	Bhringraj	Early III	Leaf	Benzene	151.38 ppm	274.34 ppm	45
				Hexane	165.10 ppm	297.70 ppm	
				Ethyl acetate	154.88 ppm	288.61 ppm	
				Methanol	127.64 ppm	245.73 ppm	
				Chloroform	146.28 ppm	274.42 ppm	
Tagetes erecta	Marigold	III	whole plant	Hydro distillation	48.951ppm	-	34
Ageratina adenophora	Sticky snakeroot	Early III	Leaf	Methanol	132.82 ppm	231.12 ppm	66
Family:-Apiaceae							
Trachyspermum ammi	Ajwain	Early IV	Fruit	Hexane	65.57ppm	108.90 ppm	28
Family:-Apocynaceae							
Thevatia peruviana	Mexican oleander	Early III	Leaf	Methanol	101.07 ppm	131.21 ppm	32
Alstonia scholaris	Scholar's tree	IV	Leaf	Acetone	239.9 ppm	501.2 ppm	3
Ervatamia coronaria	Crepe jasmine	Early III	Leaf	Methanol	65.67 mg/l	127.24 mg/L	60
Catharanthus roseus	Periwinkle	II	Leaf	Acetone	75.31 ppm	-	105
		IV			156.85 ppm		
Family:-Asclepiadaceae							
Calotropis procura	Rubberbush	Late III+Early IV	Seeds	Methanol	194.8mg/L	-	106
				Acetone	368.1mg/L		
				Petroleum ether	24.1mg/L		
				Aqueous	12.2mg/L		
Family:-Asphodaceae							
Aloe nogogenesis	Indian aloe	III	Leaf	Hexane	0.11mg/ml	0.48 mg/ml	23
				Ethyl acetate	0.15 mg/ml	0.32 mg/ml	
				Chloroform	0.34 mg/ml	0.61 mg/ml	
				Methanol	0.39 mg/ml	0.81 mg/ml	

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				Acetone	0.77 mg/ml	1.57 mg/ml	
Aloe turkanensis	Kenya aloes	III	Leaf	Ethyl acetate	0.11 mg/ml	0.19 mg/ml	
Aloe fibrosa	-	III	Leaf	Hexane	0.05mg/ml	0.09mg/ml	
				Acetone	0.67mg/ml	1.83mg/ml	
				Methanol	3.89mg/ml	7.74mg/ml	
Family:-Betulaceae							
Alnus glutinosa	Black alder	III	Old litter	Tannic Acid	7650 mg/L	-	64
Family:-Basellaceae							
Besella rubra	Malabar spinach	III	Leaf	Hexane	122.64 ppm	256.43 ppm	8
				Acetone	72.63 ppm	137.28 ppm	
				Benzene	53.62 ppm	86.42 ppm	
				Methanol	63.28 ppm	112.4 ppm	
Family:-Bignoniaceae							
Cybistax antisyphilitica	fruiting branch	-	Stem wood	Hexane	26.3 µg/ml	-	39
Adenocalymma alliaceum	Wild garlic	-	Leaf	Aqueous ext.	100% mortality at1ml for 72hrs		62
Millingtonia hortensis	Indian cork tree	IV	Leaf	Acetone	123.0 ppm	323.6 ppm	3
Spathodea campanulata	African tuliptree	I	Leaf	Aqueous ext.	4%	5.40%	107
		II			7.17%	7.74%	
		III			9.13%	10.64%	
		IV			16.12%	17.50%	
Family:-Burseraceae							
Commiphora berryi	Indian balm of Gilead	Early III	Leaf	Methanol	96.52 ppm	121.24 ppm	32
Family:-Caesulpinaceae							
Cassia tora	Sicklesenna	Early IV	Seed	Methanol	20 ppm	40.0ppm	48
Family:-Cannabaceae							
Cannabis sativa	Hemp	-	Leaf	Ethanol	5000ppm	-	53
Family:-Caulerpaceae							
Caulerpa scalpelliformis	Indian cork tree	Larvae IV	Whole plant	-	53.7 ppm	-	65
Family:-Cleomaceae							
Cleome viscose	Asian spider flower	III	Leaf	Hexane	179.26 ppm	325.64 ppm	8
				Acetone	126.12 ppm	224.16 ppm	
				Benzene	82.43 ppm	148.67 ppm	
				Methanol	123.34 ppm	216.18 ppm	
Family:-Clusiaceae							
Calophyllum inophyllum	Sultan champa	-	Leaf	Ethyl acetate	35 mg/ml	-	56
			seed	Ethyl acetate	8.2 mg/ml	-	
Family:-Cucurbitaceae							
Citrullus colocynthis	Bitter cucumber	IV	Seed	Petroleum ether	52.62 ppm	153.31 ppm	12

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Momordica charantia	Bitter gourd	Early IV	Fruit	Hexane	260.14 ppm	663.29 ppm	28
Solena amplexicaulis	Amantamal	Early III	Leaf	Ethanol	125.91 ppm	-	41
Family:-Dictyotaceae							
Dictyota dichotoma	forkweed	-	Whole plant	Acetone	61.7 ppm	-	65
Family:-Elaeaganaceae							
Elaeagnus indica	Silverberry	IV	Leaf	Acetone	90.8 ppm	217.2 ppm	13
				Ethyl acetate	151.2 ppm	456.1 ppm	
Family:-Euphorbiaceae							
Jatropa curcas	Airandi	Late III instar	Seeds	Hexane	LD50 =0.067%	LD90 = 0.14 %	7
		IV	Leaf	Petroleum ether	84.85 ppm	400.68 ppm	12
Croton bonplandianus	Three leaved caper	Early III	Leaf	Methanol	131.72 ppm	214.96 ppm	32
Euphorbia hirta	Asthma weed	Early IV	Leaf	Petroleum ether	272.36 ppm	703.76 ppm	33
Euphorbia tirucalli	Pencil tree	Early IV	Leaf	Petroleum ether	4.25 ppm	13.14 ppm	
Pedilanthus tithymaloides	Devil's backbone	Early IV	Leaf	Petroleum ether	55.26 ppm	256.77 ppm	
Codiaeum variegatum	San francisco	III to IV	Leaf	Aqueous ext.	LD 50=37.6191 g%	LD90=100.303 g%	55
Acalypha indica	Indian copperleaf	Early IV	Leaf	Acetone	251.17ppm	462.17 ppm	19
				Chloroform	588.76 ppm	1059.78ppm	
				Hexane	128.24 ppm	230.40 ppm	
				Petroleum ether	220.42 ppm	396.75 ppm	
				Ethanol	665.95 ppm	1198.85 ppm	
Ricinus communis	Castor oil plant	Early IV	Leaf	Hexane	64.26 ppm	140.18 ppm	28
Breyenia vitis -idaea	not given	III	Leaf	Hexane	126.18 ppm	354.23 ppm	44
				Chloroform	111.90 ppm	258.94 ppm	
				Ethyl acetate	98.21 ppm	130.03 ppm	
Family:-Fabaceae							
Sesbania grandiflora	Agati	III	Leaf	Hexane	208.30 mg/L	479.32 mg/L	20
				Butanol	186.90 mg/L	447.55 mg/L	
				Propanol	228.78 mg/L	539.79 mg/L	
				Ethanol	51.16 mg/L	100.87 mg/L	
Millettia pachycarpa	Fish poison climber	Early IV	Root bark	Ethanol	98.47 ppm	-	17
Acacia nilotica	Arabic gum/kikar	IV	Seeds	Petroleum benzene	45.32 mg/L	99.321mg/L	110
				Hexane	169.25 mg/L	201.623 mg/L	
				Chloroform	158.13 mg/L	198.236 mg/L	
				Ethyl acetate	59.12 mg/L	75.8216 mg/L	
				Acetone	103.68 mg/L	162.03 mg/L	
		IV	Leaf	Petroleum ether	70.42 ppm	338.10 ppm	12
Vicia tetrasperma	lentil vetch	Early IV	Seed	Methanol	100%mortality at 200 ppm dose		48

Abrus precatorius		IV	Leaf	Diethyl ether	260.77 ppm	468.65 ppm	43
				Dichloromethane	263.98 ppm	465.25 ppm	
				Ethyl acetate	251.01 ppm	445.49 ppm	
				Methanol	226.59 ppm	426.56 ppm	
				Hexane	260.80 ppm	462.57 ppm	
Family:-Geraniaceae							
Pelargonium graveolens	Rose geranium	III and IV	Whole plant	microwave assisted Hydro distillation	108.96 ppm	LC95=176.61 ppm	21
Family:-Gnetaceae							
Gnetum ula	-	Early III	Leaf	Ethanol	135.1 ppm	-	41
Family:-Leguminosae							
Milletia dura	mubatia	II	Seed	Chloroform	3.5 µg/ml	-	108
Derris species	common erris	-	Root	Ethanol	8.54µg/ml	-	15
Erythrina mulungu	Mulungu		Stem bark	Ethanol	67.9µg/ml		
Pterodon polygalaeflorus	milkworts		Seed	Ethanol	35.79µg/ml		
Cassia obtusifolia	Coffee weed	IV	Seed	Methanol	40.0 ppm	LC 95 =50ppm	48
Family:-Labiates							
Ocimum sanctum	Holy basil	Early III	Leaf	Ethyl acetate	153.39mg/L	265.67 mg/L	10
				Hexane	175.12 mg/L	290.07mg/L	
				Methanol	134.73mg/L	237.97 mg/L	
Mentha piperita	Peppermint	Early IV	Leaf	Ethanol	111.9ppm	295.18ppm	61
Minthostachys setosa	Andean mint	I	Whole plant	Dichloromethane	9.2 µg/ml	100%at25.2 µg/ml	63
Thymus vulgaris	Thyme	III+IV instar	Whole plant	microwave assisted Hydro distillation	45.73ppm	LC 95=96.26 ppm	21
Family:-Lamiaceae							
Salvia officinalis	Garden sage	III+IV instar	Whole plant	microwave assisted Hydro distillation	76.43 ppm	LC 95=123.92 ppm	21
Ocimum basilicum	Sweet basil	IV	Leaf	Ethanol	141.95 ppm	445.12 ppm	30
Ocimum gratissimum	African basil	Early IV	Leaf	Ethanol	19.50 mg/L	-	16
Family:-Liliaceae							
Aloe vera	khorpad	I	Leaf	Petroleum ether	162.74 ppm	442.98 ppm	9
		II			201.43 ppm	518.86 ppm	
		III			253.30 ppm	563.18 ppm	
		IV			300.05 ppm	612.96 ppm	
Family:-Lauraceae							
Cinnamomum camphora	camphor	-	Camphor	-	114.79 ppm	-	40
Cinnamomum microphyllum		IV	Leaf	Hydro distillation	6.7 µg/ml	-	54
Cinnamomum mollissimum		IV	Leaf	Hydro distillation	10.2µg/ml	-	

Cinnamomum rhyncophyllum		IV	Leaf	Hydro distillation	6.0 μg/ml	-	
Cinnamomum pubescens		IV	Leaf	Hydro distillation	12.8 μg/ml	-	
Cinnamomum coradatum		IV	Leaf	Hydro distillation	183.6 μg/ml	-	
Cinnamomum scotechinni		IV	Leaf	Hydro distillation	21.5 μg/ml	-	
Cinnamomum sintoc		IV	Leaf	Hydro distillation	41.1 μg/ml	-	
Cinnamomum impressicostatum		IV	Leaf	Hydro distillation	10.7 μg/ml	-	
Family:-Lythraceae							
Pemphis acidula	Small leaved mangrove	Late III	Leaf	Methanol	22.10 ppm	43.71 ppm	38
				Acetone	57.66ppm	106.51 ppm	
				Benzene	43.99ppm	84.87 ppm	
Family:-Malvaceae							
Ceiba pentandran	Kapok	Early III	Leaf	Methanol	118.85 ppm	171.40ppm	32
Abuliton indicum	Indian Mellow	Early IV	Stem	Hexane	183.61 ppm	470.48 ppm	28
Family:-Menispermiaceae							
Abuta grandifolia	Velvet leaf		Fruit	Dichloromethane	2.6 μg/ml	100% at 8.1 μg/ml	63
Family:-Meliaceae							
Azadirachta indica	Neem	Early IV	Leaf	Ethanol	8.32 mg/mL	…	16
		III to IV	Seed	Ethanol	0.017-0.0349%	Lc 99=0.1333-0.1899 g%	26
Ficus religiosa	Peepul tree	Early III	Leaf	Methanol	111.14 ppm	155.42 ppm	32
Melia dubia	Persian liliac	Early III	Leaf	Methanol	100.12 ppm	127.18 ppm	32
Lansium domesticum	Langsat	III - IV	Leaf	Aqueous ext.	LD 50=4.0282 g%	LD 90=16.3316 g%	55
Melia volkensii	Mukau	-	Fruit	Hexane : Ethyl Acetate Fraction 1:1	50 ppm	-	27
Melia azaderach	Pride of India	I	Leaf	Acetone	488.945 ppm	657.852 ppm	101
		II			515.360 ppm	716.474 ppm	
		III			531.397 ppm	657.852 ppm	
		IV			587.832 ppm	805.308 ppm	
Family:-Moraceae							
Ficus microcarpa	Chinese banyan	Early III	Leaf	Methanol	91.63 ppm	110.88 ppm	32
Family:-Myrtaceae							
Syzygium aromaticum	Clove	III	Buds	Hydro distillation	93.56 ppm	167.85 ppm	37
Syzygium cumini	Jamun	L IV	Leaf	Acetone	223.9 ppm	524.8 ppm	3
Eucalyptus globules	Bluegum	III+IV instar	Whole plant	Microwave assisted	92.55ppm	LC95=	21
				Hydro distillation		136.82 ppm	
Eucalyptus citriodora	Lemon scented gum	-	Leaf	-	91.76 ppm	-	52
Eucalyptus urophylla	Rose gum	IV	Leaf	Hydro distillation	95.5 ppm	166.3 ppm	11
Eucalyptus camaldulensis	Red river gum	IV	Leaf	Hydro distillation	31.0 ppm	71.8 ppm	11

Family:-Oleaceae							
Jasminum officinale	Jasmine	-	Flower	-	42.86ppm	-	40
Family:-Papaveraceae							
Argemone mexicana	Mexican poppy	IV	Leaf	Petroleum ether	48.99 ppm	189.10ppm	12
Family:-Pedaliaceae							
Sesamum indicum	Sesame	Early III	Leaf	Methanol	105.70 ppm	139.27 ppm	32
Family:-Piperaceae							
Piper longum	long pepper/Pipli	Early IV	Fruit exocarp	Ethanol	2.23 ppm	-	14
Piper ribesoides wall	Pippali	Early IV	Fruit exocarp	Ethanol	8.13 ppm	-	
Piper sarmentosum Roxb.	wild pepper	Early IV	Fruit exocarp	Ethanol	4.06 ppm	-	
Ottonium anisum	Saunf/anise	III	Leaf	Hexane	100% mortality at 200 µg/ml		42
Family:-Pinnaceae							
Pinus sylvestris	Pine tree	-	Needles	Hydro distillation	100.39mg/mL	142 mg/ml	49
Cedrus deodara	Deodar	-	Leaf	-	44.36 ppm	-	40
Family:-Phyllanthaceae							
Phyllanthus amarus	Hurricane weed	Early IV	Leaf	Petroleum ether	90.92 ppm	384.19 ppm	33
Phyllanthus emblica	Amla	Early IV	Fruit	hexane	298.93 ppm	454.32 ppm	28
Family:-Poaceae							
Cymbopogon flexious	Lemongrass	III	Whole plant	Hydro distillation	52.736 ppm	-	34
Coix lacryma	Job's tears	Early III	Leaf	Methanol	92.77 ppm	113.61	32
Family:-Polygalaceae							
Polygala arvensis	Field milkwort	-	Leaf	Benzene	58.21 ppm	75.32 ppm	50
				Methanol	208.45 ppm	260.45 ppm	
Family:-Rubiaceae							
Spermacoce hispida Linn.	Shaggy butterweed	Early III	Leaf	Ethanol	177.2 ppm	-	41
Anthocephalus cadamba	Kadam tree	Early III	Leaf	Ethanol	154.09 ppm	-	41
Psychotria ostosulcata	-	IV	Leaf	Chloroform	80.7 ppm	485.0 ppm	109
				Hexane	68.5 ppm	424.1 ppm	
				Ethyl acetate	65.7 ppm	360.1 ppm	
Family:-Rutaceae							
Ruta chaliphenses	Sataapha	II	Leaf	Petroleum ether	173.66 ppm	-	6
Zanthoxylum limonella Alston	Oligotrichum Tan	-	Fruit	-	24 ppm	55 ppm	59
Zanthoxylum armatum	winged prickly ash	-	Seeds	-	54 ppm	171 ppm	58
Atlantia monophylla	Wild lime	-	Leaf	Hydro distillation	93.2 ppm	146.12 ppm	103
Atlantia racemosa	Bombay atlantia	-			97.09 ppm	175.77 ppm	
Feronia limonia	Woodapple	IV	Leaf	Acetone	57.23 ppm	-	102
Glycosmis pentaphylla	Orange berry	IV	Leaf	Acetone	0.0585mg/mL	303.746mg/mL	47

				Methanol	0.121mg/mL	637.845mg/mL	
				Chloroform	0.112mg/mL	31.385mg/mL	
				Ethyl acetate	0.204mg/mL	22.687mg/mL	
Toddalia asiatica	Wild orange tree	I	Leaf	Hydro distillation	29.90 µg/ml	86.0 µg/ml	125
		II			31.75 µg/ml	110.97 µg/ml	
		III			54.70 µg/ml	296.38 µg/ml	
		IV			86.63 µg/ml	500.97 µg/ml	
Citrus citratus	Lemongrass	Early IV	Leaf	Ethanol	34.67 mg/mL	-	16
Family:-Rhizophoraceae							
Rhizophora mucronata	Red mangrove	Late IV	Bark	Ethanol	0.03µg/ml	0.0915µg/ml	51
			Leaf		0.078µg/ml	0.087µg/ml	
			Hypocotyl		0.053µg/ml	0.1037µg/ml	
			Stilt root		0.0275µg/ml	0.0675µg/ml	
			Collar		0.0673µg/ml	0.1097µg/ml	
Rhizophora apiculata	not given	Late IV	Bark	Ethanol	0.0943µg/ml	0.148 µg/ml	
			Leaf		0.085µg/ml	0.198 µg/ml	
			Hypocotyl		0.083 µg/ml	0.1303 µg/ml	
			Collar		0.0846 µg/ml	0.1283 µg/ml	
Bruguiera cylindrica	Bakau putih	Late IV	Leaf	Ethanol	0.091µg/ml	0.1109µg/ml	
			Hypocotyl		0.082µg/ml	0.121 µg/ml	
Ceriops decandra	Mangrove	Late IV	Leaf		0.0892µg/ml	0.129 µg/ml	
			Collar		0.082µg/ml	0.130 µg/ml	
Family:-Sapindaceae							
Dodonaea viscose	Vilayati Mehandi	II	Leaf	Petroleum ether	126.18 ppm	-	6
Family:-Solanaceae							
Cestrum nocturnum	Raatrani	III	Leaf	Ethyl aeetate		300 µg/ml	118
				Methanol		65 µg/ml	
Datura stramonium	Jimsonweed	LateIII/early IV	Leaf	Ethanol	LD50=86.25 ppm	LD 90=196.38 ppm	18
Withania somnifera	Indian ginseng	Iv	Leaf	Petroleum ether	89.19 ppm	281.34 ppm	12
Solanum nigrum	black nightshade		Leaf	Hexane	269.25 mg/L	623.51 mg/L	20
				Butanol	328.03 mg/L	911.4 mg/L	
				Propanol	94.33 mg/L	216.40 mg/L	
				Ethanol	34.12 mg/L	88.11 mg/L	
solanum villosum	Red nightshade	I	Berry	Chloroform: methanol	11.67 ppm	-	117
		III			22.06 ppm		
		IV			49.84 ppm		
Family:-Thymelaeaceae							
Dirca palustries	Leatherwood	IV	Seeds	Methanol	Ld 50=100	-	57

					µg/ml		
Aquilaria malaecensis	Agarwood	Late III	Wood	Hydro distillation	20.19 mg/L	-	104
Family:-Umbelliferae							
Apium graveolens	Wild Celery	IV	Seed	Methanol	-	50 µg/ml	5
Family:-Valerianaceae							
Valeriana jatamansi Bal (o)	Indian valerian	-	Root	-	51.2 mg/L	-	35
Family:-Verbenaceae							
Lantana camera	Raimuniya	II	Leaf	Petroleum ether	136.89 ppm	-	6
Family:-Zingiberaceae							
Curcuma longa L	Turmeric	IV	-	Hydro distillation	115.6 ppm	193.3 ppm	124
Curcuma xanthorrhiza	Java ginger	Late III	Rhizome	Hexane	26.4 µg/ml	-	36
				Dichloromethane	65.9 µg/ml		
				Ethyl acetate	52.6 µg/ml		
				Methanol	68.6 µg/ml		
Zingiber officinale	Garden ginger	IV	Rhizome	Petroleum ether	4.25 ppm	-	22
Curcuma heyneana Val.&Zijp		III- IV	Rhizome	Ethanol	35.33 µg/ml	86.02 µg/ml	119
Zingiber officinale	Garden ginger	IV	Leafs	Hydro distillation	40.5 ppm	85.53 ppm	124

3. DISCUSSION

Control of vector mosquito borne diseases is becoming too major challenge due to resistance in mosquito species, surveillance of vector and expansion of its boundary of distribution. Mosquitoes have developed its resistance system against used insecticides. Therefore, researchers devoted to find out an alternative, permanent, eco-friendly remedy against mosquito control strategies from natural sources. It may be in the form of essential oils, tablets, creams, sticks. Thus, it may plays an important role in the interruption of transmission of mosquito borne diseases at individual as well as community level [121].

Botanical compounds are rich in bioactive components so they may serve as a very good alternative source for control of mosquitoes [111]. Mosquitoes developed genetic resistance to both synthetic insecticides [113] and also to some bio-pesticides like *Bacillus sphaericus* [112]. Innumerable plant extracts were tested against different larval instars of mosquitoes shows promising potential larvicidal activity. Earlier study observed that phytochemicals plays a major role in mosquito control programme and observed the presence of carbohydrates, saponins, phytosterols, phenols, f lavonoids, tannins in the plant extracts possess mosquito larvicidal activity [114,115]. For instance, *Eucalyptus camadulensis* shown excellent inhibitory effects against dengue vector *Aedes aegypti* and *Aedes albopictus*[11].The bioactive components found in the leaves extracts of *Eucalyptus camadulensis* and effective against *Aedes aegypti* larvae are alpha-phellandrene, limonene, p-cymene, gamma –terpiene, terpinolene and alpha terpiene [11]. Rahuman et al (2000) studied the effectiveness of n-hexadecanoic acid in leaves extract of *Feronia limonia* as larvicidal against IV instar larvae of all major genera of mosquitoes [102]. The bioactive components isolated by GC-MS in the hexane leaf extract of *A. indica* and reported to possess larvicidal actions were Benzene, 1, 2, 3-trimethyl (1.08%), piperidine-2-5-dione 69(2.78%), 3, 7, 11, 15-Tetramethyl-2-hexadecen-1-01 (9.89%), n-Hexadecanoic acid (11.57%), phytol (12.94%), 9, 12, 15-octadecatrienoic acid (43.89%), octadecanoic acid (2.54%), 9, 12, octadecanoic acid(0.88%), heptacosane (1.75%) and squalene (12.69%)[19]. The bioactive components oleic acid and linoleic acid in the methanolic extraction of seeds of *Dirca palustris* exhibits LD50 values of 100µg/ml [57]. In the hydro distillate of seed essential oil of *Acacia nilotica* contains molecules of hexadecane and heptacosane as cidal agent [11]. In the bioassay guided fractionation of *Achranthes aspera* saponin was isolated and found to be effective as larvicidal against *Aedes aegyti* with LC50 values of 18.20 ppm [29]. Vector control program should focus attention on eliminating mosquitoes at larval stages using plant extracts. The advantage of targeting larvae is that they cannot escape from their breeding sites until adult emergence and also reduces overall use of pesticides to control adult mosquitoes by aerial application of adulticidal chemicals [116]. So easiest way to monitor the mosquito population aims to interrupt the mosquito life cycle during larval development [123].

4. CONCLUSION

The use of plant derivatives such as essential oils, in the production of natural larvicidal insecticides, could be a promising tool which help to reduce the spread of dengue fever. This is because these products are the natural sources of substances displaying insecticidal activity against mosquito (affecting the different stages of mosquito development). In addition, these products are biodegradable and express low toxicity towards non target organisms. Evolution of the resistance to plant derived compounds has rarely been observed. However, it is important to standardize the procedures used for the determination of larvicidal activity. To this effect, the WHO must establish specific procedures for the control or elimination of *Aedes aegypti* larvae. Numerous articles published till date reflects high efficacy of essential oils against larvae of mosquito species. Need of time is to initiate the large scale commercial production of encapsulated tablets, granules of essential oils, Bonide Mosquito Beater or Bonide Neem oil like products for cosmopolitan vector control.

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