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NIGERIAN PLANTS WITH INSECTICIDAL POTENTIALS AGAINST VARIOUS STAGES OF MOSQUITO DEVELOPMENT

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ABSTRACT

Mosquito transmits vector-borne disease such as malaria, filariasis, yellow fever, dengue fever, encephalitis especially in the tropical countries. In Nigeria, malaria is transmitted by female Anopheles mosquitoes. Others such as Aedes aegypti transmit chikungunya, yellow and dengue fevers; and Culex quinquefasciatus transmits lymphatic filariasis. Synthetic chemicals currently used for the control of mosquito at various developmental changes have adverse effect on the environment and non-target organisms. As such, research has focused on the use of plant extracts using different solvent. Several plants found in Nigeria have exhibited activities toward the various developmental stages of the mosquito. Therefore, research should focus on field trials against specific species of mosquitoes to determine the actual toxicity level for each species.

Keywords: Medicinal Plants, Mosquito, Nigeria, Parasites

INTRODUCTION

Insects are known to transmit diseases especially in tropical and subtropical regions of the world. Diseases transmitted by insects are major health problems globally especially in the tropics [1]. Mosquito, an iniquitous dipteran fly [2] is one of the major insects that transmit diseases. As such, mosquito is one of the most important vectors of certain human infections and diseases [3].

Diseases transmitted by mosquitoes have encroached the world since time immemorial [4]. As such, mosquitoes have co-existed with humans for several thousands of years [5]. Till date, several species of mosquito exist and belong to Order Diptera (Insecta) and Family Culicidae with three subfamilies including Anophelinae, Culicinae and Toxorhynchitinae [2,6]. Globally about 3,500 species of mosquitoes are available [2,6,7]. Within the family, several genera also exist causing several diseases. Specifically, Anopheles mosquito is the insect vectors that transmit plasmodium that causes malaria [8]. According to Ivoke *et al*. [3], out of the 42 genera of this family; the genus *Aedes*, *Culex*, *Anopheles* and *Mansonia* transmit most of the vital diseases that affect humans and animals.

Out of the 4 predominant genera that transmit diseases in animals and human, their geographical distribution appears to vary within the tropics. For instance, in countries that malaria is endemic the genus *Anopheles* is common in such areas. Generally, *Anopheles gambiae, A. funestus, A. arabiensis and A. melas* are the major vectors of human malaria [9, 10].

In the sub-Saharan Africa, *A. gambiae* and *A. arabiensis* are the dominant malaria vectors [11, 12]. *Culex quinquefasciatus*, a culicine mosquito is known to transmit lymphatic filariasis [2, 13]. *Aedes aegypti* is the main vector of diseases like chikungunya, yellow and dengue fevers [14]. Dengue fever is a major cause of child morbidity and hospitalisation in some nations in the Asian and Africa continents [14]. Specifically, yellow fever is prevalent in Nigeria and many other countries in the tropical region [14].

Mosquitoes are found in different areas including moist areas such as stagnant water, slow flowing water, flowing water with several blockage such as wastes and macrophytes and dirty environments. In Nigeria mosquitoes are common in the area with large surface water (creek, creeklets, stream, pond, rivers). Mosquitoes constitute a nuisance [15] during sleeping due to the noise they make in addition to blood sucking. The biting is usually intense around 6 to 7 a.m, with maximum intensity between 10 pm and 4 am under the Nigerian climatic conditions [2, 16]. Among the different species, Subramaniam *et al*. [17] reported that *Aedes aegypti* is a cosmotropical species that proliferates in water containers in and around houses.

Mosquitoes transmit several diseases. Akinkurolere *et al*. [8] and Owoeye *et al*. [11], estimated that mosquito transmits diseases to over 700 million people yearly in some countries in Africa, South America, Central America, Mexico and much of Asia leading to deaths of millions of people.

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Malaria is one of the predominant disease vectored by mosquitoes and is endemic in over 109 countries, infecting 190-330 million people and causing about 1 million deaths per annum [2, 11, 18]. For instance in 2010, out of the 216 million cases of malaria, 81% was in the African region. As such, global malaria burden is excessively high in Sub-Saharan Africa with 88% and 90% cases and deaths respectively resulting from malaria [19].

According to Aju-Ameh *et al*. [19], approximately 15 countries account for 80% and 78% of cases and deaths resulting from malaria worldwide. The Nigeria Malaria Fact Sheet [20] reported that nearly half of world malaria cases occur in Nigeria, Democratic Republic of Congo (DRC), Ethiopia, and Uganda. This suggests that the vector that transmits malaria is high in these regions of the world.

Again significant populations of Nigerians are at risk to malaria. Malaria, vectored by female Anopheles mosquito is a major cause of death globally especially in the Sub-Sahara Africa [5].

As such the controls of mosquitoes have assumed global importance [7]. Several insecticides are used to control mosquitoes but they are challenged by twin problems including effects on non-target organisms and development of resistance [17, 21 – 24]. Some of the chemically formulated insecticides act as carcinogenic agents and may find their way to the food chain during use where they may affect non-target organisms [17].

Again owning to the toxicity of the synthetic or chemical insecticides on non-target organisms, research, and insecticidal formulations should be focused on alternatives that are eco-friendly and biodegradable [21]. Plants have emerged as credible alternatives to the chemical based insecticides for the eradication and control of mosquitoes. According to El Maghrbi [22], the use of plant extracts for the control of mosquitoes can be traced back to ancient times. Phytochemical and bioactive components of some plants make them suitable materials for insecticides against vectors like mosquitoes [11].

According to Richa *et al*. [5], for effective control of mosquitoes, research should focus on smart and innovative techniques to control mosquitoes which involve the understanding of the fundamental biology and physics of the vector. A review on the medicinal plants with antimalarial properties in Nigeria has been comprehensively documented by Adebayo and Krettli [25]. Therefore, this review focuses on the various Nigerian plants that have insecticidal potentials against mosquitoes.

Effects of mosquitoes on humans

Mosquitoes are generally found underground cement tanks, ground level tanks, fountains, wells, mill hydrant tanks, cattle troughs and ponds which serve as breeding grounds. This could have stemmed from the fact that water is essential for the vector to complete its life cycle. As such mosquitoes, especially the larvae, are associated with permanent water bodies [26]

Mosquitoes are important blood sucking vectors that transmit a wide range of diseases [27]. They are tiny biological vectors that have the tendency to transmit most of life threatening diseases like malaria, filariasis, yellow fever, dengue fever, encephalitis *etc*. especially in the tropical world [1 - 3, 13, 22, 28 – 36]. Due to the diseases they cause, mosquitoes are a major source of morbidity and mortality among humans and livestock [22]. As such they have negative economic impact (including loss in commercial and labor outputs) in the society [22] and social disruption [34 – 36]. Due to the different diseases transmitted no part of the world in completely free from vector-borne diseases [22].

Mosquitoes constitute a nuisance during sleep. They have the tendency to cause allergic responses (local skin and systemic reactions, such as angioedema) in human populations [1] and sometimes in animals. Due to the fact that they are vectors to several diseases, and are endemic in Nigeria, substantial amounts of money are spent for treatment of diseases vectored by mosquitoes especially malaria.

Nigerian plants with insecticidal potentials

The control of mosquitoes is a major challenge especially in Sub Sahara Africa. Controlling mosquitoes could improve environmental quality and public health status of individuals living in countries that mosquito is endemic [37]. The control of diseases transmitted by mosquitoes is carried out by eradicating the various developmental stages of the vector. These include the egg, larva, pupa and adult stages. The larvae stage is the most susceptible to any treatment and restricted to their common aquatic habitats [38] such as stagnant and slow flowing water.

Synthetic chemical insecticides typically made from organochlorine and organophosphate compounds are used to control mosquitoes [37]. Due to the challenges (effect on non-targets organisms including humans, non-degradability, biomagnification in the food chain/web and adverse environment impacts) confronting the use of convention synthetic/chemical insecticides [32, 37], research have focused on the use of plant extracts.

Several plant species have demonstrated potentials against the various development phases of the mosquito. This could be due to the effects of secondary metabolites they contain [24, 39]. Notable metabolites that play essential role toward the efficacy of plant extracts toward mosquito include Alkaloids, terpenoids, steroids, etc. [24, 40]. As such various plant extracts are therefore being studied for their potential efficacy to minimize the adverse effects associated with chemical insecticides and control mosquito at various developmental stages (ovicidal, larvicidal, pupacidal and adult).

According to Sukumar *et al*. [41] and Raja *et al*. [24], over 344 plant species have the tendency to be used for the control of mosquitoes. Tables 1 to 3 present some major plants found in Nigeria that have exhibited positive effects for the control of adult, larva and pupa of mosquito. The occurrence of plant species depend on the geographic coverage and the knowledge of the residents of such areas about their medicinal properties. Some authors have demonstrated the mosquito repellent activities of some plants in some regions in Nigeria. For instance, Edwin-Wosu *et al*. [42] listed 24 plant species belonging to 16 families as mosquito repellent plants in South-Eastern, Nigeria. Egunyomi *et al*. [39] reported that the leaves of *Azadirachta indica, Cymbopogon citratus, Ocimum gratissimum, Ageratum conyzoides, Annona squamosa,*

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Hyptis suaveolens, Tridax procumbens, Lantana camara and *Solanum nigrum* and fruit peels of *Citrus sinensis* are effective against the malarial fever mosquito in Ibadan, Nigeria.

Dried plants either in dried state or extracted with solvents can be used to control various stages of mosquito development. They can either be used out rightly in repelling adult mosquito (preventing mosquito bites) or extracted using various solvents such as ethanol, methanol, n-hexane, chloroform, ethyl acetate, petroleum ether, water etc. The different plant parts (stem, leaves, root, flower, fruits) also play different role in the control of mosquitoes (Table 1-3). The activities of plants against mosquito developmental stages differ depending on the biochemical compositions of the plant. The solvents used for the extraction of the plant materials also play a significant role in the insecticidal potential of plants against mosquitos. This could be difference in polarity level of the phytochemical constituents of plants.

The concentration of the plant used also determines the repellent potential of such plants. For instance, Ojewumi and Owolabi [43] reported that 20g of active ingredient of *Hyptis Sauveolens* could repel mosquito for 2- 3 hours for 0.25ml, 5-6 hours for 30ml and 9 – 10hours for 50ml. At different developmental stages of mosquito, the effect (mortality level) varies (Table 1 – 3). Furthermore, Ayange-Kaa *et al*. [44] reported the effect of dried leaves of *Hyptis suaveolens* on various stages of mosquito development in Benue state and reported 99.2% efficacy at 450mg/ml (ovicidal), 51.3% at 500mg/ml (larva and adult) and 43.8% (pupacidal). Rwang *et al*. [45] reported that aqueous and ethanolic leave extracts of *Psidium guajava* has larvicidal activity against the mosquito larvae at 20 minutes interval. The authors asserted that ethanolic extracts had superior effect compared to aqueous extracts for the control of mosquito larva. As such the effectiveness of the plant materials could largely depend on the concentration applied.

Table 1: Plant with repellant properties against adult mosquito

Plant	Mosquito species	Plant part	Solvent	Concentration of the extracts	Effects/ Mortality/LC values	References
Alstonia boonei	*Anopheles gambiae*	Leaves	Acetone	1 -5%	88.26% mortality after 24 hours at 5% concentration; LC_{50} = 2.08	[46]
Alstonia boonei	*Anopheles gambiae*	Stem bark	Acetone	1 -5%	96% mortality after 24 hours at 5% concentration; LC_{50}= 0.82	[46]
Alstonia boonei	*Anopheles gambiae*	Root	Acetone	1 -5%	78% mortality after 24 hours at 5% concentration; LC_{50}= 2.14	[46]
Anacardium occidentale	*Anopheles gambiae*	Seed	Hexane	0.1 – 0.5%	75.3% mortality at 0.5% concentration after 24 hours; LC_{50} = 0.28	[8]
Cassia mimosoides	*Anopheles gambiae*	Leaves and pod	Petroleum either	Cream 0 – 6% w/w	100% mortality at 2%w/w after 5 minutes	[1]
Datura stramonium	*Anopheles gambiae*	Leaves	n-hexane, petroleum ether and ethanol	0.1 -1.0%	57.50 % mortality was achieved at 1.0% extract after 1 hour	[11]
Myrianthus arboreus	*Anopheles gambiae*	Bark	Ethanol	0.1 – 0.5%	52.50% mortality at 0.5% concentration after 24 hours; LC_{50} = 0.32	[8]
Nicotiana tabacum	*Anopheles gambiae*	Leaves	n-hexane, petroleum ether and ethanol	0.1 -1.0%	0% mortality was achieved at 1.0% extract after 1 hour	[11]
Ocimum gratissimum	*Anopheles gambiae*	Leaves	Powder	1-5g	Percentage mortality of 93.33, 100, 80, 66.67 and 100% were achieved at 1, 2, 3, 4 and 5g of the extract at 30 hours. 100% mortality for the various concentration were achieved at 36 hours	[23]
Ocimum gratissimum	*Anopheles gambiae*	Oil from leaves	Oil	5 – 25ml	Percentage mortality 60, 36.67, 76.67, 36.67 and 56.67 % were achieved at 5, 10, 15, 20 and 25ml of the oil at 24 hours. 100% mortality for the various concentration were achieved at 30 hours	[23]
Ocimum gratissimum	*Anopheles gambiae*	wax candle	wax candle	0.1 – 0.5g/mol	Percentage mortality of 50, 60, 60, 70 and 100% were achieved at 0.1, 0.2, 0.3, 0.4 and 0.5g/mol of the extract at 30 hours. 100% mortality for the various concentration were achieved at 36 hours	[23]
Piper guineense	*Anopheles gambiae*	Leaves	n-hexane, petroleum ether and ethanol	0.1 -1.0%	0% mortality was achieved at 1.0% extract after 1 hour	[11]
Xylopia aethiopica	*Anopheles gambiae*	Fruit	Ethanol	0.1 – 0.5%	92.5% mortality at 0.5% concentration after 24 hours; LC_{50} = 0.23	[8]

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Table 2: Nigerian Plants with Larvacidal properties

Plant	Mosquito species	Plant part	Solvent	Concentration of the extracts	Effects/ Mortality	References
Abrus precatorius	*Aedes aegypti*	seed	Methanol	-	LC_{50} =0.85	[14]
Allium sativum	*Culex quinquefasciatus*	garlic bulb	Ethanol	-	The LC_{50} values 2nd, 3rd and 4th larval instars were 144.54, 165.70 and 184.18 ppm respectively.	[47]
Alstonia boonei	*Aedes aegypti*	Leaves	Methanol	-	ND	[14]
Alstonia boonei	*Anopheles gambiae*	Leaves	Acetone	1 -5%	96.50% mortality after 24 hours at 5% concentration; LC_{50}= 1.38	[46]
Alstonia boonei	*Anopheles gambiae*	Stem bark	Acetone	1 -5%	100% mortality after 24 hours at 5% concentration; LC_{50}= 0.80	[46]
Alstonia boonei	*Anopheles gambiae*	Root	Acetone	1 -5%	86.51% mortality after 24 hours at 5% concentration; LC_{50}= 2.64	[46]
Anacardium occidentale	*Anopheles gambiae*	Seed	Hexane	0.1 – 0.5%	100% mortality at 0.5% concentration after 24 hours; LC_{50} = 0.34	[8]
Annona senegalensis	*Anopheles gambiae*	Leaves	Methanolic Crude Extract	0 – 2000ppm	At 125ppm, mortality was 69.67% at 24 hours; LC_{50}= 973.3	[15]
Annona senegalensis	*Anopheles gambiae*	Leaves	n-hexane fraction	0 – 2000ppm	At 125ppm, mortality was 62.67% at 24 hours; LC_{50}= 298.8	[15]
Annona senegalensis	*Anopheles gambiae*	Leaves	Chloroform fraction	0 – 2000ppm	At 125ppm, mortality was 79% at 24 hours; LC_{50}= 418.3	[15]
Annona senegalensis	*Anopheles gambiae*	Leaves	Ethyl-Acetate Fraction	0 – 2000ppm	At 125ppm, mortality was 96.33% at 24 hours; LC_{50}= 2789.3	[15]
Annona senegalensis	*Anopheles gambiae*	Leaves	Methanol fraction	0 – 2000ppm	At 125ppm, mortality was 98.67% at 24 hours; LC_{50}= 8511.4	[15]
Annona senegalensis	*Culex quinquefasciatus*	Leaves	Methanolic Crude Extract	0 – 2000ppm	At 125ppm, mortality was 98% at 24 hours; LC_{50}= 5884.1	[15]
Annona senegalensis	*Culex quinquefasciatus*	Leaves	n-hexane fraction	0 – 2000ppm	At 125ppm, mortality was 88% at 24 hours; LC_{50}= 2807.6	[15]
Annona senegalensis	*Culex quinquefasciatus*	Leaves	Chloroform fraction	0 – 2000ppm	At 125ppm, mortality was 96.67% at 24 hours; LC_{50}= 9010.1	[15]
Annona senegalensis	*Culex quinquefasciatus*	Leaves	Ethyl-Acetate Fraction	0 – 2000ppm	At 125ppm, mortality was 100% at 24 hours	[15]
Annona senegalensis	*Culex quinquefasciatus*	Leaves	Methanol fraction	0 – 2000ppm	At 125ppm, mortality was 100% at 24 hours	[15]
Artocarpus altilis	*Aedes aegypti*	Stem bark	Methanol	-	LC_{50} =3.90	[14]
Artocarpus altilis	*Aedes aegypti*	Wood	Methanol	-	LC_{50} =6.38	[14]
Avicennia germinans	*Anopheles gambiae*	Leaves	Chloroform	150 – 100ppm	Induced total mortality above 500 ppm	[48]
Avicennia germinans	*Anopheles gambiae*	Leaves	Methanol	150 – 100ppm	LC_{50}= 247.5ppm	[48]
Avicennia germinans	*Anopheles gambiae*	Leaves	Hexane	150 – 100ppm	LC_{50}= 250.50ppm	[48]
Azadirachta indica	*Anopheles gambiae*	Root	Chloroform	0 – 250ppm	LC_{50}= 40.00ppm	[49]
Azadirachta indica	*Anopheles gambiae*	Root	Hexane	0 – 250ppm	LC_{50}= 28.03 ppm	[49]
Azadirachta indica	*Anopheles gambiae*	Root	Acetone	0 – 250ppm	LC_{50}= 39.82 ppm	[49]
Azadirachta indica	*Anopheles gambiae*	Root	Ethanol	0 – 250ppm	LC_{50}= 21.50 ppm	[49]
Azadirachta indica	*Anopheles gambiae*	Stem bark	Chloroform	0 – 250ppm	LC_{50}= 13.50 ppm	[49]

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Azadirachta indica	*Anopheles gambiae*	Stem bark	Hexane	0 – 250ppm	LC_{50}= 11.02 ppm	[49]
Azadirachta indica	*Anopheles gambiae*	Stem bark	Acetone	0 – 250ppm	LC_{50}= 12 14ppm	[49]
Azadirachta indica	*Anopheles gambiae*	Stem bark	Ethanol	0 – 250ppm	LC_{50}= 6.50	[49]
Azadirachta indica	*Culex* sp	leaves	petroleum ether	20 – 50%	100% mortality was achieved at 40% of the extract after 24 hours; LC_{50}= 14.3	[36]
Azadirechta indica	*Aedes aegypti*	Leaves	Ethanol	2.5 – 50mg/ml	At 50mg/ml concentration, mortality of 52% was achieved at 24 hours and at 25mg/l and 37.5mg/ml concentration mortality was also at 52%; LC_{50}= 8.32mg/ml	[50]
Balanites aegyptiaca	Fourth instar mosquito larvae	Leaves	Ethanol	2 -10ppm	At 10ppm, there was 66% mortality; LC_{50}= 6.70	[51]
Balanites aegyptiaca	Fourth instar mosquito larvae	Root	Ethanol	2 -10ppm	At 10ppm, there was 73.67% mortality; LC_{50}= 6.61	[51]
C. citratus	*Aedes aegypti*	Leaves	Ethanol	2.5 – 50mg/ml	At 50mg/ml concentration, mortality of 52% was achieved at 24 hours; LC_{50}= 19.50mg/ml	[50]
Calotropis procera	Fourth instar mosquito larvae	Leaves	Ethanol	2 -10ppm	At 10ppm, there was 64.67% mortality; LC_{50}= 6.99	[51]
Calotropis procera	Fourth instar mosquito larvae	Root	Ethanol	2 -10ppm	At 10ppm, there was 65% mortality; LC_{50}= 6.92	[51]
Canna indica	*Aedes aegypti*	leaves	Methanol	-	LC_{50} =3.84	[14]
Cassia mimosoides	*Anopheles gambiae*	Leaves and pod	Petroleum either	0.25 – 2mg/ml	LC_{50}= 0.28mg/ml at 24 hours of exposure	[1]
Cassia mimosoides	*Anopheles gambiae*	Leaves and pod	Dichloromet hane	0.25 – 2mg/ml	LC50= 0.41mg/ml at 24 hours of exposure	[1]
Cassia mimosoides	*Anopheles gambiae*	Leaves and pod	Ethanol	0.25 – 2mg/ml	LC50= 4.85mg/ml at 24 hours of exposure	[1]
Cassia mimosoides	*Anopheles gambiae*	Leaves and pod	Water	0.25 – 2mg/ml	LC_{50}= 5.53 mg/ml at 24 hours of exposure	[1]
Cleistopholis patens	*Aedes aegypti*	Leaves	Methanol	-	LC_{50} =4.41	[14]
Cola gigantean	Anopheles stephensi	Leaves	n-Hexane	2 -10ml	At 10ml of the extract, 82% mortality were achieved at 24 hours; LC_{50}= 108.16	[52]
Costus afer	*Aedes aegypti*	Leaves	Methanol	-	LC_{50} =8.25	[14]
Costus afer	*Aedes aegypti*	Stem	Methanol	-	LC_{50} =9.00	[14]
Croton zambesicus	Anopheles stephensi	Leaves	n-Hexane	2 -10ml	At 10ml of the extract, 94% mortality were achieved at 24 hours; LC_{50}= 155.19	[52]
Curcuma longa	*Aedes aegypti*	Rhizome	Methanol	-	LC_{50} =2.62	[14]
Curcuma longa	Anopheles gambiae	Oil from Leave	Ethanol	0.008 - 1.00mg/ml	100% mortality at 0.500 mg/mL, with LC_{50} value of 0.029 mg/mL	[53]
Curcuma longa	Anopheles gambiae	Oil from Rhizome	Ethanol	0.008 - 1.00mg/ml	100% mortality at 0.125 with LC_{50} values of 0.017 mg/ml	[53]
Cymbopogon citratus	*Culex quinquefasciatus*	Leaves	Ethanol	62.5 – 2000mg/l	At 1500mg/l, mortality were 100% at 4 days; LC_{50}= 109.65	[54]
Dioscoreophyllum cumminsii	*Aedes aegypti*	Leaves	Methanol	-	LC_{50} =4.52	[14]
Enantia chlorantha	*Aedes aegypti*	Stem bark	Methanol	-	LC_{50} =4.55	[14]
Eucalyptus globulus	Fourth instar mosquito larvae	Leaves	Ethanol	2 -10ppm	At 10ppm, there was 63% mortality; LC_{50}= 7.94	[51]
Eucalyptus globulus	Fourth instar	Root	Ethanol	2 -10ppm	At 10ppm, there was 64.67% mortality; LC_{50}= 7.24	[51]

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	mosquito larvae					
Euphorbia heterophylla	*Aedes aegypti*	Wood	Methanol	-	ND	[14]
Hoslundia opposite	*Aedes aegypti*	Leaves	Methanol	-	LC_{50} =4.56	[14]
Hyptis lanceolata	*Culex quinquefasciatus*	Leaves	Ethanol	62.5 – 2000mg/l	At 1000mg/l, mortality were 100% at 4 days; LC_{50}= 70.79	[54]
Hyptis spicigera	*Culex quinquefasciatus*	Leaves	Ethanol	62.5 – 2000mg/l	At 1000mg/l, mortality were 100% at 4 days; LC_{50}= 52.48	[54]
Hyptis suaveolen	*Anopheles gambiae*	Leaves	Methanol	0 -500ppm	LC_{50} = 73.25ppm	[55]
Hyptis suaveolen	*Anopheles gambiae*	Leaves	Chloroform	0 -500ppm	LC_{50} =76.22ppm	[55]
Hyptis suaveolen	*Anopheles gambiae*	Leaves	Hexane	0 -500ppm	LC_{50} =97.25ppm	[55]
Hyptis suaveolens	*Culex* sp	Leaves	petroleum ether	20 – 50%	3.96% mortality was achieved at 40% of the extract after 24 hours; LC_{50}= 66.40	[36]
Hyptis suaveolens	*Culex quinquefasciatus*	Leaves	Ethanol	62.5 – 2000mg/l	At 1000mg/l, mortality were 100% at 4 days; LC_{50}= 70.79	[54]
Hyptis suaveolens	*Anopheles gambiae*	Leaves	Ethanol	-	LC_{50}= 62.41	[3]
Hyptis suaveolens	*Anopheles gambiae*	Leaves	Aqueous	-	LC_{50}= 80.02	[3]
Jimson weed (*Datura stramonium*)	*Anopheles gambiae*	Leaves	n-hexane, petroleum ether and ethanol solution	0.1 -1.0%	100% mortality was achieved at 0.8% extract after 1 hour with LC95 =0.67ml	[11]
L. camara + O. gratissimum	*Aedes aegypti*	Leaves	Methanol crude extract	0 – 2 g/l	100% mortality was achieved at 2g/l after 24 hours; LC_{50}= 0.63	[34]
L. camara + O. gratissimum	*Aedes aegypti*	Leaves	Hexane fraction	0 – 2 g/l	100% mortality was achieved at 1 g/l after 24 hours; LC_{50}= 0.36	[34]
L. camara + O. gratissimum	*Aedes aegypti*	Leaves	Chloroform fraction	0 – 2 g/l	53.33% mortality was achieved at 2g/l after 24 hours; LC_{50}= 1.83	[34]
L. camara + O. gratissimum	*Aedes aegypti*	Leaves	Ethyl acetate fraction	0 – 2 g/l	62.66 % mortality was achieved at 2g/l after 24 hours; LC_{50}= 0.70	[34]
L. camara + O. gratissimum	*Aedes aegypti*	Leaves	Methanol fraction	0 – 2 g/l	100 % mortality was achieved at 2g/l after 24 hours; LC_{50}= = 0.64	[34]
Landolphia owariensis	*Aedes aegypti*	Leaves	Methanol	-	LC_{50} = 3.84	[14]
Languncularia racemosa	*Anopheles gambiae*	Leaves	Chloroform	150 – 100ppm	Induced total mortality above 500 ppm	[48]
Languncularia racemosa	*Anopheles gambiae*	Leaves	Methanol	150 – 100ppm	LC_{50}= 228.50ppm	[48]
Languncularia racemosa	*Anopheles gambiae*	Leaves	Hexane	150 – 100ppm	LC_{50}= 308.50ppm	[48]
Lantana camara	*Culex quinquefasciatus*	Leaves	Ethanol	62.5 – 2000mg/l	At 1000mg/l, mortality were 100% at 4 days; LC_{50}= 56.23	[54]
Lantana camara	*Aedes aegypti*	Leaves	Methanol crude extract	0 – 2 g/l	100% mortality was achieved at 2g/l after 24 hours; LC_{50}= 0.96	[34]
Lantana camara	*Aedes aegypti*	Leaves	Hexane fraction	0 – 2 g/l	100% mortality was achieved at 2g/l after 24 hours; LC_{50}= 0.72	[34]
Lantana camara	*Aedes aegypti*	Leaves	Chloroform fraction	0 – 2 g/l	41.33% mortality was achieved at 2g/l after 24 hours; LC_{50}= 2.2	[34]
Lantana camara	*Aedes aegypti*	Leaves	Ethyl acetate fraction	0 – 2 g/l	100% mortality was achieved at 2g/l after 24 hours; LC_{50}= 0.62	[34]
Lantana camara	*Aedes aegypti*	Leaves	Methanol fraction	0 – 2 g/l	21.33% mortality was achieved at 2g/l after 24 hours; LC_{50}= 3.26	[34]
Malacantha alnifolia	Anopheles stephensi	Leaves	n-Hexane	2 -10ml	At 10ml of the extract, 100% mortality were achieved at 24 hours; LC_{50}= 193.74	[52]
Mangifera indica	*Aedes aegypti*	Leaves	Methanol	-	LC_{50}= 8.57	[14]
Murraya koenigii	*Aedes aegypti*	Leaves	Methanol	-	LC_{50} =4.83	[14]

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Myrianthus arboreus	*Anopheles gambiae*	Bark	Ethanol	0.1 – 0.5%	92.5% mortality at 0.5% concentration after 24 hours; LC_{50} = 0.36	[8]
Nicotiana tabacum	*Anopheles gambiae*	Leaves	n-hexane, petroleum ether and ethanol	0.1 -1.0%	77% mortality was achieved at 1.0% extract after 1 hour with LC_{95} =1.07ml	[11]
Ocimum gratissimum	*Aedes aegypti*	Leaves	Ethanol	2.5 – 50mg/ml	At 50mg/ml concentration, mortality of 20% was achieved at 24 hours and at 25mg/l and 37.5mg/ml concentration mortality was also at 24%; LC_{50}= 34.67mg/ml	[50]
Ocimum gratissimum	*Culex quinquefasciatus*	Leaves	Aqueous	6.25 – 1000ppm	49% mortality at 1000ppm after 48 hours; LC_{50} = 36.1ppm	[55]
Ocimum gratissimum	*Culex quinquefasciatus*	Leaves	Ethanol	6.25 – 1000ppm	80% mortality at 50ppm after 24 hours; LC_{50} = 3.6ppm	[55]
Ocimum gratissimum	*Culex quinquefasciatus*	Leaves	Ethyl acetate	6.25 – 1000ppm	44% mortality at 1000ppm after 24 hours; LC_{50} = 7.7ppm	[55]
Ocimum gratissimum	*Culex quinquefasciatus*	Leaves	n-hexane	6.25 – 1000ppm	48% mortality at 1000ppm after 48 hours; LC_{50} = 2.5ppm	[55]
Ocimum gratissimum	*Culex quiquefasciatus*	Leaves	n-hexane	0 – 8%	100% mortality was achieved after 24 hours at 4% concentration of the extract; LC_{50}= 0.11	[56]
Ocimum gratissimum	*Culex quiquefasciatus*	Leaves	Acetone	0 – 8%	100% mortality was achieved after 24 hours at 8% concentration of the extract; LC_{50}= 2.89	[56]
Ocimum gratissimum	*Culex quiquefasciatus*	Leaves	Ethanol	0 – 8%	100% mortality was achieved after 24 hours at 8% concentration of the extract; LC_{50}= 0.66	[56]
Ocimum gratissimum	*Culex quiquefasciatus*	Leaves	70% methanol	0 – 8%	100% mortality was achieved after 24 hours at 2% concentration of the extract; LC_{50}= 0.11	[56]
Ocimum gratissimum	*Culex* sp	Leaves	petroleum ether	20 – 50%	100% mortality was achieved at 50% of the extract after 24 hours; LC_{50}= 11.4	[36]
Ocimum gratissimum	*Aedes aegypti*	Leaves	Methanol crude extract	0 – 2 g/l	100% mortality was achieved at 2g/l after 24 hours; LC_{50}= 0.6	[34]
Ocimum gratissimum	*Aedes aegypti*	Leaves	Hexane fraction	0 – 2 g/l	100% mortality was achieved at 1 g/l after 24 hours; LC_{50}= 0.37	[34]
Ocimum gratissimum	*Aedes aegypti*	Leaves	Chloroform fraction	0 – 2 g/l	72% mortality was achieved at 2g/l after 24 hours; LC_{50}= 1.6	[34]
Ocimum gratissimum	*Aedes aegypti*	Leaves	Ethyl acetate fraction	0 – 2 g/l	90.66% mortality was achieved at 2g/l after 24 hours; LC_{50}= 0.97	[34]
Ocimum gratissimum	*Aedes aegypti*	Leaves	Methanol fraction	0 – 2 g/l	10.66% mortality was achieved at 2g/l after 24 hours; LC_{50}= 3.26	[34]
Ocimum sanctum	*Anopheles gambiae*	Leaves	Methanol	0 -500ppm	LC_{50} =125ppm	[57]
Ocimum sanctum	*Anopheles gambiae*	Leaves	Chloroform	0 -500ppm	LC_{50} =150ppm	[57]
Ocimum sanctum	*Anopheles gambiae*	Leaves	Hexane	0 -500ppm	LC_{50} =194.08ppm	[57]
Piper guineense	*Anopheles gambiae*	Leaves	n-hexane, petroleum ether and ethanol	0.1 -1.0%	100% mortality was achieved at 0.1% extract after 1 hour with LC_{95} =0.10ml	[11]
Piper nigrum	*Aedes aegypti*	Seed	Methanol	-	LC_{50}= 0.01	[14]
Rhizophora mangle	*Anopheles gambiae*	Leaves	Chloroform	150 – 100ppm	LC50= 225.0ppm	[48]
Rhizophora mangle	*Anopheles gambiae*	Leaves	Methanol	150 – 100ppm	LC50= 179.38ppm	[48]
Rhizophora mangle	*Anopheles gambiae*	Leaves	Hexane	150 – 100ppm	LC50= 275.63ppm	[48]
Rhizophora racemosa	*Anopheles gambiae*	Leaves	Chloroform	150 – 100ppm	LC50= 175.00ppm	[48]
Rhizophora racemosa	*Anopheles gambiae*	Leaves	Methanol	150 – 100ppm	LC50=150.00ppm	[48]
Rhizophora	*Anopheles*	Leaves	Hexane	150 – 100ppm	LC50=225.00ppm	[48]

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racemosa	*gambiae*					
Senecio biafrae	*Aedes aegypti*	Whole plant	Methanol	-	LC_{50} =4.73	[14]
Solanum xanthocarpum	culicine species	Root	Aqueous	1-5ml	At 5ml of the extract, mortality were 66.67% and 100% at 24 and 48 hours respectively	[57]
Solanum xanthocarpum	culicine species	Seed	Aqueous	1-5ml	Mortality were 90.67% at 5ml of extract at 24 hours and 100% at 1ml of extract at 48 hours	[57]
Spondias mombin	*Aedes aegypti*	Leaves	Methanol crude extract	125 – 1000ppm	100% mortality was achieved at 1000ppm of the extract after 24 hours; LC_{50}= 205.23	[58]
Spondias mombin	*Aedes aegypti*	Leaves	Hexane extract	125 – 1000ppm	100% mortality was achieved at 250ppm of the extract after 24 hours; LC_{50}= 22.54	[58]
Spondias mombin	*Aedes aegypti*	Leaves	Dichloro-methane fraction	125 – 1000ppm	100% mortality was achieved at 250ppm of the extract after 24 hours; LC_{50}= 42.13	[59]
Spondias mombin	*Aedes aegypti*	Leaves	Acetone	125 – 1000ppm	100% mortality was achieved at 250ppm of the extract after 24 hours; LC_{50}= 45.18	[59]
Spondias mombin	*Aedes aegypti*	Leaves	Ethyl acetate fraction	125 – 1000ppm	100% mortality was achieved at 500ppm of the extract after 24 hours; LC_{50}= 56.84	[59]
Spondias mombin	*Aedes aegypti*	Leaves	Methanol fraction	125 – 1000ppm	100% mortality was achieved at 500ppm of the extract after 24 hours; LC_{50}= 40.65	[59]
Spondias mombin	*Anopheles gambiae*	Leaves	Methanol crude extract	125 – 1000ppm	100% mortality was achieved at 1000ppm of the extract after 24 hours; LC_{50}= 186.18	[59]
Spondias mombin	*Anopheles gambiae*	Leaves	Hexane extract	125 – 1000ppm	100% mortality was achieved at 500ppm of the extract after 24 hours; LC_{50}= 92.2	[59]
Spondias mombin	*Anopheles gambiae*	Leaves	Dichloro-methane fraction	125 – 1000ppm	100% mortality was achieved at 1000ppm of the extract after 24 hours; LC_{50}= 165.1	[59]
Spondias mombin	*Anopheles gambiae*	Leaves	Acetone	125 – 1000ppm	100% mortality was achieved at 1000ppm of the extract after 24 hours; LC_{50}= 257.36	[59]
Spondias mombin	*Anopheles gambiae*	Leaves	Ethyl acetate fraction	125 – 1000ppm	69.330% mortality was achieved at 1000ppm of the extract after 24 hours; LC_{50}= 754.50	[59]
Spondias mombin	*Anopheles gambiae*	Leaves	Methanol fraction	125 – 1000ppm	53.33% mortality was achieved at 1000ppm of the extract after 24 hours; LC_{50}= 911.06	[59]
Spondias mombin	*Culex quinquefasciatus*	Leaves	Methanol crude extract	125 – 1000ppm	42.67% mortality was achieved at 1000ppm of the extract after 24 hours; LC_{50}= 1150.59	[59]
Spondias mombin	*Culex quinquefasciatus*	Leaves	Hexane extract	125 – 1000ppm	96% mortality was achieved at 1000ppm of the extract after 24 hours; LC_{50}= 326.52	[59]
Spondias mombin	*Culex quinquefasciatus*	Leaves	Dichloro-methane fraction	125 – 1000ppm	6.67% mortality was achieved at 1000ppm of the extract after 24 hours; LC_{50}= 6086.77	[59]
Spondias mombin	*Culex quinquefasciatus*	Leaves	Acetone	125 – 1000ppm	44% mortality was achieved at 1000ppm of the extract after 24 hours; LC_{50}= 1039.4	[59]
Spondias mombin	*Culex quinquefasciatus*	Leaves	Ethyl acetate fraction	125 – 1000ppm	14.67% mortality was achieved at 1000ppm of the extract after 24 hours; LC_{50}= 2618.52	[59]
Spondias mombin	*Culex quinquefasciatus*	Leaves	Methanol fraction	125 – 1000ppm	4% mortality was achieved at 1000ppm of the extract after 24 hours; LC_{50}= 8749.97	[59]
Xylopia aethiopica	*Anopheles gambiae*	Fruit	Ethanol	0.1 – 0.5%	100% mortality at 0.5% concentration after 24 hours; LC_{50} = 0.29	[8]
Zingiber officinale	*Culex quinquefasciatus*	Rhizome	Ethanol	62.5 – 2000mg/l	At 1000mg/l, mortality were 100% at 4 days; LC_{50}= 79.43	[54]

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Table 3: Nigeria plants with insecticidal properties against Pupa stage of mosquito

Plant	Mosquito species	Plant part	Solvent	Concentration of the extracts	Effects/ Mortality/LC values	References
Alstonia boonei	*Anopheles gambiae*	Leaves	Acetone	1 -5%	88.2% mortality after 24 hours at 5% concentration; LC_{50}= 3.06	[46]
Alstonia boonei	*Anopheles gambiae*	Stem bark	Acetone	1 -5%	96% mortality after 24 hours at 5% concentration; LC_{50}= 1.02	[46]
Alstonia boonei	*Anopheles gambiae*	Root	Acetone	1 -5%	78% mortality after 24 hours at 5% concentration; LC_{50}= 0.80	[46]
Anacardium occidentale	*Anopheles gambiae*	Seed	Hexane	0.1 – 0.5%	47.5% mortality at 0.5% concentration after 24 hours; LC_{50} = 0.45	[8]
Datura stramonium	*Anopheles gambiae*	Leaves	n-hexane, petroleum ether and ethanol	0.1 -1.0%	100% mortality was achieved at 0.1% extract after 1 hour with LC_{95} =0.19ml	[11]
Myrianthus arboreus	*Anopheles gambiae*	Bark	Ethanol	0.1 – 0.5%	25.5% mortality at 0.5% concentration after 24 hours; LC_{50} = 0.64	[8]
Nicotiana tabacum	*Anopheles gambiae*	Leaves	n-hexane, petroleum ether and ethanol	0.1 -1.0%	60% mortality was achieved at 1.0% extract after 1 hour with LC_{95} =0.91ml	[11]
Piper guineense	*Anopheles gambiae*	Leaves	n-hexane, petroleum ether and ethanol	0.1 -1.0%	100% mortality was achieved at 0.1% extract after 1 hour with LC_{95} =0.10ml	[11]
Xylopia aethiopica	*Anopheles gambiae*	Fruit	Ethanol	0.1 – 0.5%	57.5% mortality at 0.5% concentration after 24 hours; LC_{50} = 0.40	[8]

CONCLUSION AND THE WAY FORWARD

Mosquito, a protozoan, is known to transmit several diseases. Mosquito transmits several diseases. The spread of the diseases that are transmitted by vectors could be controlled by eradicating the various stages of development of the vector. Mosquitoes typically complete their life cycle in water. Several chemical insecticides are used for controlling the vectors at its various stages of development. But due to the potential effect of the synthetic insecticides on non-target organisms and adverse environmental effect, research has focused on plant extracts as potential alternatives. In Nigeria, several plant species have demonstrated activities against mosquito at its various stage of development. Some of this plants include *Zingiber officinale, Xylopia aethiopica, Spondias mombin, Solanum xanthocarpum, Senecio biafrae, Rhizophora racemosa, Rhizophora mangle, Piper nigrum, Piper guineense, Ocimum sanctum, Ocimum gratissimum, Nicotiana tabacum, Myrianthus arboreus, Murraya koenigii, Mangifera indica, Malacantha alnifolia, Lantana camara, Languncularia racemosa, Landolphia owariensis, Datura stramonium, Hyptis suaveolens, Hyptis spicigera, Hyptis lanceolata, Hoslundia opposite, Euphorbia heterophylla, Eucalyptus globulus, Eucalyptus globulus, Enantia chlorantha, Dioscoreophyllum cumminsii, Cymbopogon citratus, Curcuma longa, Croton zambesicus, Costus afer, Cola gigantean, Cleistopholis patens, Cassia mimosoides, Canna indica, Calotropis procera, Balanites aegyptiaca, Azadirechta indica, Avicennia germinans, Artocarpus altilis, Annona senegalensis, Anacardium occidentale, Alstonia boonei, Abrus precatorius, Allium sativum* among others. Based on the activity of each plant, several solvents have showed efficacy against the different developmental stages. Due to the polarity difference in the phytochemical constitutes of the plants no specific solvent is preferred for all plants. Again, due to the fact that plants are either hydrophobic or hydrophilic when they go into solution, the activeness varies depending on the solvent used for extraction. Furthermore, the age of the plant and season the plant was harvested may have an effect on the efficacy of the insecticidal tendency of the plants. As such, research should be focused on field trials against specific species of the various developmental stages of the mosquito to determine the actual toxicity levels.

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