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Mosquito control management using phytochemicals: A review

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Abstract
Mosquitoes are the most dangerous vectors of diseases belonging to arthropod family. They are important in public health because of the blood-sucking habits of the females. Mosquitoes were declared as the "public enemy number one" by WHO. Mosquito-borne diseases are increasing due to having dirty places near residential area containing still water, lack of cleanness in public places and decreasing immunity. Mosquitoes are known to transmit some dangerous diseases, including malaria, dengue, yellow fever, filariasis, Zika fever, encephalitis, chikungunya fever, West Nile virus infection in almost all tropical and subtropical countries as well as many other parts of the world. A large number of researchers are evaluating botanical extracts containing active phytochemicals to address some of these problems. From early human ages, various plants that contain toxic chemicals are used for mosquito control. Studies and research on mosquito control are generally aimed at cost reduction and increasing efficacy. This review summarizes research and studies that were conducted previously by researchers on mosquito controlling using botanical pesticides.

Keywords: Larvicidal effects, botanical extracts, mosquito larvae, LC_{50}

Introduction
Among the group of arthropods, mosquitoes are known to transmit more diseases and affect millions of people around the world (Thiyagarajan *et al.* 2014) [44]. It is estimated that mosquitoes transmit diseases to more than 700 million people annually and are responsible for the deaths of about one in every 17 people (WHO 2005) [47]. Mosquitoes can thrive in almost all environments, excluding extreme cold weather. They like Places such as marshes, forests, weeds, tall grasses, tree holes that periodically hold water, and those places that are wet at least part of the year (Tamara *et al.* 2005) [43]. Synthetic insecticides like organochlorine and organophosphate compounds are used as principal weapons in mosquito control operations (Ghosh *et al*. 2012) [7]. But, the use of synthetic insecticides has brought side-effects in non-targeted organisms. Human beings are using plants for insecticide purposes from early human history. Botanical insecticides are more useful than chemical or synthetic insecticides as they are less toxic to non-target organisms, less prone to develop resistance and are biodegradable. Several species of plants have been exploited throughout the world to check mosquito populations. The current review summarizes research and studies that were done previously by researchers on mosquito control using botanical pesticides.

Methods and Materials
A large number of works have been done throughout the world on mosquito control management using phytochemicals. To evaluate and compare the efficacy of various toxic extracts of seed and leaf of different plants against the mosquito larvae, all relevant and available articles were searched and downloaded from the google search engine. All articles related to the control of mosquito larvae *Culex quinquefasciatus* were compared with one another (Table- 1) according to their LC_{50} values. This rule was also followed for the articles related to the larvae of *Culex pipiens* (Table-2), *Aedes aegypti* (Table-3), *Aedes albopictus* (Table-4), *Anopheles stephensi* (Table-5), and *Anopheles gambiae* (Table-6).

Results

Toxicological effects of various plants seed and leaf extracts were evaluated against the mosquito larvae at various concentrations under normal laboratory conditions.

Table 1: Efficacy of botanical extracts in controlling *Culex quinquefasciatus* Say larvae

Plant species	Family	Plant parts	Extract	LC_{50} values	References
Jatropha curcas	Euphorbiaceae	Leaf	Petroleum ether extract	11.34 ppm	Rahuman *et al*. (2007) [32]
Pedilanthus tithymaloides	Euphorbiaceae	Leaf	Petroleum ether extract	76.61 ppm	
Phyllanthus amarus	Phyllanthaceae	Leaf	Petroleum ether extract	113.40 ppm	
Argemone mexicana	Papaveraceae	Leaf	Petroleum ether extract	250 ppm	Karmegan *et al*. (1996) [14]
Jatropha curcus	Euphorbiaceae	Leaf	Petroleum ether extract	250 ppm	
Pergularia extensa	Asclepiadaceae	Leaf	Petroleum ether extract	250 ppm	
Withania somnifera	Solanaceae	Leaf	Petroleum ether extract	250 ppm	
Euphorbia hirta	Euphorbiaceae	Stem bark	Petroleum ether extract	424.94 ppm	Rahuman *et al*. (2008) [33]
E. tirucalli	Euphorbiaceae	Stem bark	Petroleum ether extract	5.52 ppm	
Ocimum basilicum	Lamiaceae	Leaf	Petroleum ether extract	87.68 ppm	Maurya *et al*. (2009) [22]
Kaempferia galanga	Zingiberaceae	Rhizome	Hexane extract	42.33 ppm	Choochote *et al*. (1999)
Solanum nigrum	Solanaceae	Dried fruit	Hexane extract	12.25 ppm	Raghavendra *et al*. (2009) [30]
Solanum nigrum	Solanaceae	Dried fruit	Aqueous extract	337.2 ppm	
Eucalyptus citriodora	Myrtaceae	Leaf	Hexane extract	81.12 ppm	Singh *et al*. (2007) [40]
Solanum nigrum	Solanaceae	Leaf	Ethyl acetate extract	17.04 ppm	Rawani *et al*. (2010) [35]
Ocimum gratissimum	Lamiaceae	Leaf	Ethyl acetate extract	66.28 µg/ml	Kamaraj & Rahuman (2010) [11]
Annona squamosa	Annonaceae	Bark	Ethyl acetate extract	43.07 ppm	Kamaraj *et al*. (2010) [12]
Ocimum sanctum	Labiate	Leaf	Ethyl acetate extract	592.60 ppm	Anees (2008) [1]
Solanum villosum	Solanaceae	Leaf	Aqueous extract	645.75 ppm	Chowdhury *et al*. (2008) [3]
Piper retrofractum	Piperaceae	Unripe and ripe fruit	Aqueous extract	135 ppm	Chansang *et al*. (2005) [2]
Millingtonia hortensis	Bignoniaceae	Leaf	Acetone extract	83.18 ppm	Kaushik & Saini (2008) [13]
Feronia limonia	Rutaceae	Leaf	Acetone extract	129.24 ppm	Rahuman *et al*. (2000) [31]
Ageratina adenophora	Asteraceae	Twigs	Acetone extract	227.20 ppm	Raj Mohan & Ramaswamy (2007) [29]
Nyctanthes arbortristi	Nyctantheceae	Flower	Chloroform extract	25.67 ppm	Khatune *et al*. (2001) [15]
Acalypha alnifolia	Euphorbiaceae	Leaf	Methanol extract	128.55 ppm	Kovendan *et al*. (2012) [16]
Coccinia indica	Cucurbitaceae	Leaf	Methanol extract	377.69 ppm	Rahuman & Venkatesan (2008) [33]
Cucumus sativus	Cucurbitaceae	Leaf	Methanol extract	623.80 ppm	
Momordica charantia	Cucurbitaceae	Leaf	Methanol extract	207.61 ppm	
Pavonia zeylanica	Malvaceae	Leaf	Methanol extract	2214.7 ppm	Vahitha *et al*. (2002) [46]
Acacia ferruginea	Leguminosae	Leaf	Methanol extract	5362.6 ppm	
Vitex negundo	Verbenaceae	Leaf	Methanol extract	212.57 ppm	Krishnan *et al*. (2007) [17]
V. trifolia	Verbenaceae	Leaf	Methanol extract	41.41 ppm	
V. peduncularis	Verbenaceae	Leaf	Methanol extract	76.28 ppm	
V. altissima	Verbenaceae	Leaf	Methanol extract	128.04 ppm	
Momordica charantia	Cucurbitaceae	Leaf	Methanol extract	465.85 ppm	Prabakar & Jebanesan (2004) [27]
Trichosanthes anguina	Cucurbitaceae	Leaf	Methanol extract	567.81 ppm	
Luffa acutangula	Cucurbitaceae	Leaf	Methanol extract	839.81 ppm	
Benincasa cerifera	Cucurbitaceae	Leaf	Methanol extract	1189.30 ppm	
Citrullus vulgaris	Cucurbitaceae	Leaf	Methanol extract	1636.04 ppm	
Citrus reticulata	Rutaceae	Seed	Ethanol Extract	2,639.27 ppm	Sumroiphon *et al*. (2006) [42]

Rahuman *et al*. (2007) [32] surveyed larvicidal activity of Petroleum ether extract of *Jatropha curcas*, *Pedilanthus tithymaloides* and *Phyllanthus amarus* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} values of these plants were 11.34 ppm, 76.61 ppm and 113.40 ppm respectively. Karmegan *et al*. (1996) [14] studied on larvicidal activity of Petroleum ether extract of *Argemone Mexicana*, *Jatropha curcus*, *Pergularia extensa* and Withania somnifera leaf against *Culex quinquefasciatus* Say larvae. LC_{50} values of all of these plants were 250 ppm. Rahuman *et al*. (2008) [33] evaluated larvicidal activity of Petroleum ether extract of *Euphorbia hirta* and *E. tirucalli* stem bark against *Culex quinquefasciatus* Say larvae. LC_{50} values of these plants were 424.94 ppm and 5.52 ppm respectively. Maurya *et al*. (2009) [22] tested larvicidal activity of Petroleum ether extract of *Ocimum basilicum* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 87.68 ppm. Choochote *et al*. (1999) studied larvicidal activity of Hexane extract of *Kaempferia galanga* Rhizome against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 42.33 ppm. Raghavendra *et al*. (2009) [30] studied larvicidal activity of Hexane extract of Dried fruit of *Solanum nigrum* and *Solanum nigrum*. LC_{50} values of these plants were 12.25 ppm and 337.2 ppm respectively. Singh *et al*. (2007) [40] evaluated larvicidal activity of Hexane extract of *Eucalyptus citriodora* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 81.12 ppm. Rawani *et al*. (2010) [35] surveyed larvicidal activity of Ethyl acetate extract of *Solanum nigrum* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 17.04 ppm. Kamaraj & Rahuman (2010) [11] surveyed larvicidal activity of Ethyl acetate extract of *Ocimum gratissimum* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 66.28 µg/ml. Kamaraj *et al*. (2010) [12] evaluated larvicidal activity of Ethyl acetate

extract of *Annona squamosal* bark against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 43.07 ppm. Anees (2008) [1] surveyed larvicidal activity of Ethyl acetate extract of *Ocimum sanctum* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 592.60 ppm. Chowdhury *et al*. (2008) [3] studied on larvicidal activity of aqueous extract of *Solanum villosum* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 645.75 ppm. Chansang *et al*. (2005) [2] studied larvicidal activity of aqueous extract of Unripe and ripe fruit of *Piper retrofractum* against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 135 ppm. Kaushik & Saini (2008) [13] evaluated larvicidal activity of Acetone extract of *Millingtonia hortensis* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 83.18 ppm. Rahuman *et al*. (2000) [31] evaluated larvicidal activity of Acetone extract of *Feronia limonia* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 129.24 ppm. Raj Mohan & Ramaswamy (2007) [29] evaluated larvicidal activity of Acetone extract of twigs of *Ageratina adenophora* against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 227.20 ppm. Khatune *et al*. (2001) [15] tested larvicidal activity of Chloroform extract of flower of *Nyctanthes arbortristi* against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 25.67 ppm. Kovendan *et al*. (2012) [16] tested larvicidal activity of Methanol extract of *Acalypha alnifolia* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 128.55 ppm. Rahuman & Venkatesan (2008) [33] tested larvicidal activity of Methanol extract of *Coccinia indica, Cucumus sativus* and *Momordica charantia* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} values of these plants were 377.69 ppm, 623.80 ppm and 207.61 ppm respectively. Vahitha et al. (2002) [46] worked on larvicidal activity of Methanol extract of *Pavonia zeylanica* and *Acacia ferruginea* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} values of these plants were 2214.7 ppm and 5362.6 ppm respectively. Krishnan *et al*. (2007) [17] evaluated larvicidal activity of Methanol extract of *Vitex negundo, V. trifolia, V. peduncularis* and *V. altissima* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} values of these plants were 212.57 ppm, 41.41 ppm, 76.28 ppm and 128.04 ppm respectively. Prabakar & Jebanesan (2004) [27] tested larvicidal activity of Methanol extract of *Momordica charantia, Trichosanthes anguina, Luffa acutangula, Benincasa cerifera* and *Citrullus vulgaris* leaf against *Culex quinquefasciatus* Say larvae. LC_{50} values of these plants were 465.85 ppm, 567.81 ppm, 839.81 ppm, 1189.30 ppm and 1636.04 ppm respectively. Sumroiphon *et al*. (2006) [42] tested larvicidal activity of Ethanol extract of *Citrus reticulate* seeds against *Culex quinquefasciatus* Say larvae. LC_{50} value of this plant was 2,639.27 ppm.

Table 2: Efficacy of botanical extracts in controlling *Culex pipiens* larvae

Plant species	Family	Plant parts	Extract	LC_{50} values	References
Cassia tora	Caesulpinaceae	Seed	Methanol extract	20 mg/l	Jang *et al*. (2002) [9]
Solanum xanthocarpum	Solanaceae	Root	Methanol extract	248.55 ppm	Mohan *et al*. (2006) [24]
Solamum xanthocarpum	Solanaceae	Root	Carbon tetra chloride extract	64.99 ppm	
Solanum xanthocarpum	Solanaceae	Root	Petroleum ether extract	41.28 ppm	
Euphorbia tirucalli	Euphorbiaceae	Latex and stem bark	Methanol extract	177.14 mg/l	Yadav *et al*. (2002) [48]
Euphorbia tirucalli	Euphorbiaceae	Latex and stem bark	Chloroform extract	200.76 mg/l	
Piper nigrum	Piperaceae	Seed	Petroleum ether extract	2.6 mg/l	Shaalan *et al*. (2005) [39]
Thymus capitatus	Lamiaceae	Leaf	Petroleum ether extract	49.0 ppm	Mansour *et al*. (2000) [19]
Myrtus communis	Myrtaceae	Flower and Leaf	Petroleum ether extract	16 mg/ l	Traboulsi *et al*. (2002) [45]

Jang *et al*. (2002) [9] tested larvicidal activity of Methanol extract of *Cassia tora* seeds against *Culex pipiens* larvae. LC_{50} value of this plant was 20 mg/l. Mohan *et al*. (2006) [24] evaluated larvicidal activity of Methanol, Carbon tetra chloride and Petroleum ether extract of *Solanum xanthocarpum* root against *Culex pipiens* larvae. LC_{50} values of these extracts were 248.55 ppm, 64.99 ppm and 41.28 ppm respectively. Yadav *et al*. (2002) [48] studied on larvicidal activity of Methanol and Chloroform extract of Latex and stem bark of *Euphorbia tirucalli* against *Culex pipiens* larvae. LC_{50} values of these extracts were 177.14 mg/l and 200.76 mg/l respectively. Shaalan *et al*. (2005) [39] worked on larvicidal activity of Petroleum ether extract of *Piper nigrum* seeds against *Culex pipiens* larvae. LC_{50} value of this plant was 2.6 mg/l. Mansour *et al*. (2000) [19] tested larvicidal activity of Petroleum ether extract of *Thymus capitatus* leaf against *Culex pipiens* larvae. LC_{50} value of this plant was 49.0 ppm. Traboulsi *et al*. (2002) [45] tested larvicidal activity of Petroleum ether extract of flower and leaf of *Myrtus communis* against *Culex pipiens* larvae. LC_{50} value of this plant was 16 mg/ l.

Table 3: Efficacy of botanical extracts in controlling *Aedes aegypti* larvae

Plant species	Family	Plant parts	Extract	LC_{50} values	References
Azadirechta indica	Meliaceae	Leaf	Ethanol Extract	8.32 mg/ml	Mgbemena (2010) [23]
Ocimum gratissimium	Lamiaceae	Leaf	Ethanol Extract	19.50mg/ml	
Citrus citratus	Rutaceae	Leaf	Ethanol Extract	34.67mg/ml	
Rhizophora mucronata	Rhizophoraceae	Bark	Ethanol Extract	157.4 ppm	Kabaru & Gichia (2001) [10]
Rhizophora mucronata	Rhizophoraceae	pith	Ethanol Extract	168.3 ppm	
Rhizophora mucronata	Rhizophoraceae	stem wood	Ethanol Extract	1003.4 ppm	
Annona crassiflora	Annonaceae	Root wood	Ethanol Extract	0.71 µg/ml	Omena *et al*. (2007) [26]
Annona crassiflora	Annonaceae	Root bark	Ethanol Extract	8.94 µg/ml	
Annona crassiflora	Annonaceae	Stem	Ethanol Extract	16.1 µg/ml	
A. glabra	Annonaceae	Seed	Ethanol Extract	0.06 µg/ml	

A. muricata	Annonaceae	Root	Ethanol Extract	42.3 µg/ml	
A. squamosa	Annonaceae	Root	Ethanol Extract	31.9 µg/ml	
A. squamosa	Annonaceae	Leaf	Ethanol Extract	169 µg/ml	
Denis sp.	Leguminoseae	Root	Ethanol Extract	8.54 µg/ml	
Erythrina mulungu	Leguminoseae	Stem bark	Ethanol Extract	67.9 µg/ml	
Pterodon polygalaeflorus	Leguminoseae	Seed	Ethanol Extract	35.7 µg/ml	
Curcuma aromatica	Zingiberaceae	Rhizome	Hexane extract	36.30 ppm	Choochate *et al*. (2005) [5]
Cybistax antisyphilitica	Bignoniaceae	Stem wood	Hexane extract	26.3 µg/ml	Rodrigues *et al*. (2005) [36]
Eucalyptus citriodora	Myrtaceae	Leaf	Hexane extract	91.76 ppm	Singh et al (2007) [40]
Solanum nigrum	Solanaceae	Dried fruit	Hexane extract	17.63 ppm	Raghavendra *et al*. (2009) [30]
Solanum nigrum	Solanaceae	Dried fruit	Aqueous extract	359 ppm	
Ageratina adenophora	Asteraceae	Twigs	Acetone extract	356.70 ppm	Raj Mohan & Ramaswamy (2007) [29]
Feronia limonia	Rutaceae	Leaf	Acetone extract	57.23 ppm	Rahuman *et al*. (2000) [31]
Millingtonia hortensis	Bignoniaceae	Leaf	Acetone extract	138 ppm	Kaushik & Saini (2008) [13]
O. sanctum	labiate	Leaf	Acetone extract	425.94 ppm	Anees (2008) [1]
Cassia tora	Caesulpinaceae	Seed	Methanol extract	20 mg/l	Jang *et al*. (2002) [9]
C. vulgaris	Cucurbitaceae	Leaf	Benzene extract	42.76 ppm	Mullai *et al*. (2008) [25]
Piper retrofractum	Piperaceae	Un ripe and ripe fruit	Aqueous extract	79 ppm	Chansang *et al*. (2005) [2]
Solanum villosum	Solanaceae	Leaf	Aqueous extract	747.22 ppm	Chowdhury *et al*. (2008) [3]

Mgbemena (2010) [23] studied on larvicidal activity of Ethanol Extract of *Azadirechta indica, Ocimum gratissimium* and *Citrus citratus* leaf against *Aedes aegypti* larvae. LC_{50} values of these plants were 8.32 mg/m, 19.50mg/ml and 34.67mg/ml respectively. Kabaru & Gichia (2001) [10] tested larvicidal activity of Ethanol Extract of bark, pith and stem wood of *Rhizophora mucronata* against *Aedes aegypti* larvae. LC_{50} value of bark, pith and stem wood were 157.4 ppm, 168.3 ppm and 1003.4 ppm respectively. Omena *et al*. (2007) [26] evaluated larvicidal activity of Ethanol Extract of root wood, root bark and stem of *Annona crassiflora,* seed of *A. glabra*, root of *A. muricata*, root and leaf of *A. squamosal*, root of *Denis sp*., stem bark of *Erythrina mulungu* and seed of *Pterodon polygalaeflorus* against *Aedes aegypti* larvae. LC_{50} values were 0.71 µg/ml, 8.94 µg/ml, 16.1 µg/ml, 0.06 µg/ml, 42.3 µg/ml, 31.9 µg/ml, 169 µg/ml, 8.54 µg/ml, 67.9 µg/ml and 35.7 µg/ml respectively. Choochate *et al*. (2005) [5] tested larvicidal activity of Hexane extract of Rhizome of *Curcuma aromatica* against *Aedes aegypti* larvae. LC_{50} value of this plant was 36.30 ppm. Rodrigues *et al*. (2005) [36] evaluated larvicidal activity of Hexane extract of stem wood of *Cybistax antisyphilitica* against *Aedes aegypti* larvae. LC_{50} value of this plant was 26.3 µg/ml. Singh *et al*. (2007) [40] tested larvicidal activity of Hexane extract of *Eucalyptus citriodora* leaf against *Aedes aegypti* larvae. LC_{50} value of this plant was 91.76 ppm. Raghavendra *et al*. (2009) [30] studied on larvicidal activity of Hexane extract and Aqueous extract of Dried fruit of *Solanum nigrum* against *Aedes aegypti* larvae. LC_{50} values of these extracts were 17.63 ppm and 359 ppm respectively. Raj Mohan & Ramaswamy (2007) [29] worked on larvicidal activity of Acetone extract of *Ageratina adenophora* against *Aedes aegypti* larvae. LC_{50} value of this plant was 356.70 ppm. Rahuman *et al*. (2000) [31] worked on larvicidal activity of Acetone extract of *Feronia limonia* leaf against *Aedes aegypti* larvae. LC_{50} value of this plant was 57.23 ppm. Kaushik & Saini (2008) [13] worked on larvicidal activity of Acetone extract of *Millingtonia hortensis* leaf against *Aedes aegypti* larvae. LC_{50} value of this plant was 138 ppm. Anees (2008) [1] studied on larvicidal activity of Acetone extract of *O. sanctum* leaf against *Aedes aegypti* larvae. LC_{50} value of this plant was 425.94 ppm. Jang *et al*. (2002) [9] worked on larvicidal activity of Methanol extract of *Cassia tora* seeds against *Aedes aegypti* larvae. LC_{50} value of this plant was 20 mg/l. Mullai *et al*. (2008) [25] evaluated larvicidal activity of Benzene extract of *C. vulgaris* against *Aedes aegypti* larvae. LC_{50} value of this plant was 42.76 ppm. Chansang *et al*. (2005) [2] evaluated larvicidal activity of Aqueous extract of Un ripe and ripe fruit of *Piper retrofractum* against *Aedes aegypti* larvae. LC_{50} value of this plant was 79 ppm. Chowdhury *et al*. (2008) [3] surveyed larvicidal activity of aqueous extract of *Solanum villosum* leaf against *Aedes aegypti* larvae. LC_{50} value of this plant was 747.22 ppm.

Table 4: Efficacy of botanical extracts in controlling *Aedes albopictus* larvae

Plant species	Family	Plant parts	Extract	LC_{50} values	References
Coccinia indica	Cucurbitaceae	Leaf	Methanol extract	309.46 ppm	Rahuman & Venkatesan (2008) [33]
Cucumis sativus	Cucurbitaceae	Leaf	Methanol extract	492.73 ppm	
Momordica charantia	Cucurbitaceae	Leaf	Methanol extract	199.14 ppm	
Aristolochia saccata	Aristolochiaceae	Root	Methanol extract	14.52 ppm	Das *et al*. (2007) [6]
Annona squamosa	Annonaceae	Leaf	Methanol extract	20.26 ppm	
Gymnopetelum cochinchinensis	Cucurbitaceae	pericarp	Methanol extract	50.67 ppm	
Caesalpinea sp.	Leguminosae	Bark	Methanol extract	53.66 ppm	
Piper sp.	Piperaceae	Stem	Methanol extract	144.22 ppm	

Rahuman & Venkatesan (2008) [33] tested larvicidal activity of Methanol extract of *Coccinia indica, Cucumis sativus* and *Momordica charantia* leaf against *Aedes albopictus* larvae. LC_{50} values of these plants were 309.46 ppm, 492.73 ppm and 199.14 ppm respectively. Das *et al*. (2007) [6] tested larvicidal activity of Methanol extract of *Aristolochia saccata* root, *Annona squamosal* leaf, *Gymnopetelum cochinchinensis* pericarp, *Caesalpinea sp*. Bark and *Piper sp.* stem against *Aedes albopictus* larvae. LC_{50} values of these plants were 14.52 ppm, 20.26 ppm, 50.67 ppm, 53.66 ppm and 144.22 ppm respectively.

Table 5: Efficacy of botanical extracts in controlling *Anopheles stephensi* larvae

Plant species	Family	Plant parts	Extract	LC_{50} values	References
Annona squamosa	Annonaceae	Bark	Ethyl acetate extract	28.18 ppm	Kamaraj *et al*. (2010) [12]
Solanum villosum	Solanaceae	Leaf	Aqueous extract	644.75 ppm	Chowdhury *et al*. (2008) [3]
Solanum nigrum	Solanaceae	Dried fruit	Aqueous extract	242.5 ppm	Raghavendra *et al*. (2009) [30]
Acalypha indica	Euphorbiaceae	Leaf	Benzene extract	19.25 ppm	Govindarajan *et al*. (2008) [8]
Cassia obtusifolia	Leguminosae	Leaf	Ethanol Extract	52.2 ppm	Rajkumar & Jebanesan (2009) [28]
Atlantia monophylla	Rutaceae	Leaf	Methanol extract	0.05 mg/l	Sivagnaname & Kalyanasundaram (2004) [41]
Aloe barbadensis	Liliaceae	Leaf	Carbon tetra chloride extract	15.58 ppm	Maurya *et al*. (2007) [21]
Feronia limonia	Rutaceae	Leaf	Acetone extract	79.58 ppm	Rahuman *et al*. (2000) [31]
Millingtonia hortensis	Bignoniaceae	Leaf	Acetone extract	104.70 ppm	Kaushik & Saini (2008) [13]
Eucalyptus citriodora	Myrtaceae	Leaf	Hexane extract	69.86 ppm	Singh *et al*. (2007) [40]
Solanum nigrum	Solanaceae	Dried fruit	Hexane extract	6.25 ppm	Raghavendra *et al*. (2009) [30]
Artemisia annua	Asteraceae	Leaf	Petroleum ether extract	16.85 ppm	Sharma *et al*. (2006) [38]
Acacia nilotica	Fabaceae	Leaf	Petroleum ether extract	55.72 ppm	Saktivadivel & Daniel (2008)
Argemone mexicana	Papaveraceae	Leaf	Petroleum ether extract	30.47 ppm	
Argemone mexicana	Papaveraceae	seed	Petroleum ether extract	24.17 ppm	
Jatropha curcas	Euphorbiaceae	Leaf	Petroleum ether extract	62.29 ppm	
Withania somnifera	Solanaceae	Leaf	Petroleum ether extract	65.08 ppm	
Citrullus colocynthis	Cucurbitaceae	Leaf	Petroleum ether extract	37.70 ppm	
Aloe barbadensi	Liliaceae	Leaf	Petroleum ether extract	29.06 ppm	Maurya *et al*. (2007) [21]
Cannabis sativa	Moraceae	Leaf	Petroleum ether extract	376.58 ppm	

Kamaraj *et al*. (2010) [12] studied on larvicidal activity of Ethyl acetate extract of bark of *Annona squamosal* against *Anopheles stephensi* larvae. LC_{50} value of this plant was 28.18 ppm. Chowdhury et al. (2008) [3] studied larvicidal activity of Aqueous extract of *Solanum villosum* leaf against *Anopheles stephensi* larvae. LC_{50} value of this plant was 644.75 ppm. Raghavendra *et al*. (2009) [30] tested larvicidal activity of Aqueous extract of dried fruit of *Solanum nigrum* against *Anopheles stephensi* larvae. LC_{50} value of this plant was 242.5 ppm. Govindarajan *et al*. (2008) [8] evaluated larvicidal activity of Benzene extract of *Acalypha indica* leaf against *Anopheles stephensi* larvae. LC_{50} value of this plant was 19.25 ppm. Rajkumar & Jebanesan (2009) [28] tested larvicidal activity of Ethanol extract of *Cassia obtusifolia* against *Anopheles stephensi* larvae. LC_{50} value of this plant was 52.2 ppm. Sivagnaname & Kalyanasundaram (2004) [41] tested larvicidal activity of Methanol extract of *Atlantia monophylla* against *Anopheles stephensi* larvae. LC_{50} value of this plant was 0.05 mg/l. Maurya *et al*. (2007) [21] worked on larvicidal activity of Carbon tetra chloride extract of *Aloe barbadensis* against *Anopheles stephensi* larvae. LC_{50} value of this plant was 15.58 ppm. Rahuman *et al*. (2000) [31] studied on larvicidal activity of Acetone extract of *Feronia limonia* against *Anopheles stephensi* larvae. LC_{50} value of this plant was 79.58 ppm. Kaushik & Saini (2008) [13] worked on larvicidal activity of Acetone extract of *Millingtonia hortensis* against *Anopheles stephensi* larvae. LC_{50} value of this plant was 104.70 ppm. Singh *et al*. (2007) [40] tested larvicidal activity of Hexane extract of *Eucalyptus citriodora* against *Anopheles stephensi* larvae. LC_{50} value of this plant was 69.86 ppm. Raghavendra *et al*. (2009) [30] worked on larvicidal activity of Hexane extract of Dried fruit of *Solanum nigrum* against *Anopheles stephensi* larvae. LC_{50} value of this plant was 6.25 ppm. Sharma *et al*. (2006) [38] evaluated larvicidal activity of Petroleum ether extract of *Artemisia annua* leaf against *Anopheles stephensi* larvae. LC_{50} value of this plant was 16.85 ppm. Saktivadivel & Daniel (2008) [37] evaluated larvicidal activity of Petroleum ether extract of leaf of *Acacia nilotica*, *Argemone mexicana*, *Jatropha curcas*, *Withania somnifera*, *Citrullus colocynthis* and seeds of *Argemone mexicana* against *Anopheles stephensi* larvae. LC_{50} values of these plants were 55.72 ppm, 30.47 ppm, 62.29 ppm, 65.08 ppm, 37.70 ppm and 24.17 ppm respectively. Maurya *et al*. (2007) [21] evaluated larvicidal activity of Petroleum ether extract of *Aloe barbadensi* and *Cannabis sativa* leaf against *Anopheles stephensi* larvae. LC_{50} values of these plants were 29.06 ppm and 376.58 ppm respectively.

Table 6: Efficacy of botanical extracts in controlling *Anopheles gambiae* larvae

Plant species	Family	Plant parts	Extract	LC_{50} values	References
Plumbago zeylanica	Plumbaginaceae	Root	Chloroform extract	4.1 mg/ml	Maniafu *et al*. (2009) [18]
P. dawei	Plumbaginaceae	Root	Chloroform extract	6.4 mg/ml	
P. stenophylla	Plumbaginaceae	Root	Chloroform extract	6.7 mg/ml	
Aloe ngongensis	Asphodelaceae	Leaf	Chloroform extract	58.25 mg/ml	Matasyoh *et al*. (2008) [20]
Aloe turkanensis	Asphodelaceae	Leaf	Ethyl acetate extract	0.11mg/ml	
Cleistanthus collinus	Euphorbiaceae	Leaf	Aqueous extract	409.77 ppm	Rawani *et al*. (2009) [34]

Maniafu *et al*. 2009) [18] tested larvicidal activity of Chloroform extract of root of *Plumbago zeylanica, P. dawei* and *P. stenophylla* against *Anopheles gambiae* larvae. LC_{50} values of these plants were 4.1 mg/m, 6.4 mg/ml and 6.7 mg/ml respectively. Matasyoh *et al*. (2008) [20] evaluated larvicidal activity of Chloroform extract of *Aloe ngongensis* and *Aloe turkanensis* leaf against *Anopheles gambiae* larvae. LC_{50} values of these plants were 58.25 mg/ml and 0.11mg/ml respectively. Rawani *et al*. (2009) [34] surveyed larvicidal activity of aqueous extract of *Cleistanthus collinus* leaf against *Anopheles gambiae* larvae. LC_{50} value of this plant was 409.77 ppm.

Discussion

For all of the plant's extracts used in controlling *Culex quinquefasciatus* Say larvae by different researchers, Petroleum ether extracts of stem bark of *Euphorbia tirucalli* showed the highest toxicity with the lowest LC_{50} value of 5.52 ppm (Rahuman *et al.* 2008) [33] and Methanol extracts of *Acacia ferruginea* leaf showed the lowest toxicity with the highest LC_{50} value of 5362.6 ppm (Vahitha *et al*. 2002) [46]. Petroleum ether extracts of *Piper nigrum* seed showed the highest toxicity with the lowest LC_{50} value of 2.6 mg/l (Shaalan *et al.* 2005) [39] and Methanol extracts of *Solanum xanthocarpum* root showed the lowest toxicity with the highest LC_{50} value of 248.55 ppm (Mohan *et al.* 2006) [24] in controlling *Culex pipiens* larvae. In controlling *Aedes aegypti* larvae, Ethanol extracts of seed of *Annona glabra* showed the highest toxicity with the lowest LC_{50} value of 0.06 µg/ml (Omena *et al.* 2007) [26] and Aqueous extracts of *Solanum villosum* leaf showed the lowest toxicity with the highest LC_{50} value of 747.22 ppm (Chowdhury *et al*. 2008) [3]. Methanol extracts of *Aristolochia saccata* root showed the highest toxicity with the lowest LC_{50} value of 14.52 ppm (Das *et al.* 2007) [6] and Methanol extracts of *Cucumis sativus* leaf showed the lowest toxicity with the highest LC_{50} value of 492.73 ppm (Rahuman & Venkatesan 2008) [33] in controlling *Aedes albopictus* larvae. Methanol extracts of *Atlantia monophylla* leaf showed the highest toxicity with the lowest LC_{50} value of 0.05 mg/l (Sivagnaname & Kalyanasundaram (2004) [41] and Aqueous extracts of *Solanum villosum* leaf showed the lowest toxicity with the highest LC_{50} value of 644.75 ppm (Chowdhury *et al.* 2008) [3] in controlling *Anopheles stephensi* larvae. In controlling *Anopheles gambiae* larvae, Ethyl acetate extracts of leaf of *Aloe turkanensis* showed the highest toxicity with the lowest LC_{50} value of 0.11mg/ml (Matasyoh *et al*. 2008) [20] and Aqueous extracts of *Cleistanthus collinus* leaf showed the lowest toxicity with the highest LC_{50} value of 409.77 ppm (Rawani *et al*. 2009) [34].

Conclusion

Diseases caused by mosquito vector populations are major human and animal health problems in all tropical and subtropical countries. A large number of various plant species from different geographical regions of the world have been identified to possess phytochemicals that are capable of controlling mosquito populations. Phytochemicals, obtained from plants are readily available in many parts of the world, relatively safe, inexpensive and can be used as larvicides for killing mosquito larvae or as repellents for protection against mosquito bites. Even though the evaluation of phytochemicals is yet in its preliminary stages and much of the research needs to be conducted to characterize promising agents and discover new agents, some results described in this review suggest that botanical phytochemicals should be counted as future alternative to synthetic insecticides and be used as mosquito controlling agents. Currently, phytochemicals make one percent of world's pesticide market. Identifying insecticides of botanical origin that are effective and suitable to local ecological conditions, biodegradable will work as a new weapon in the future to fight against mosquito-borne diseases.

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