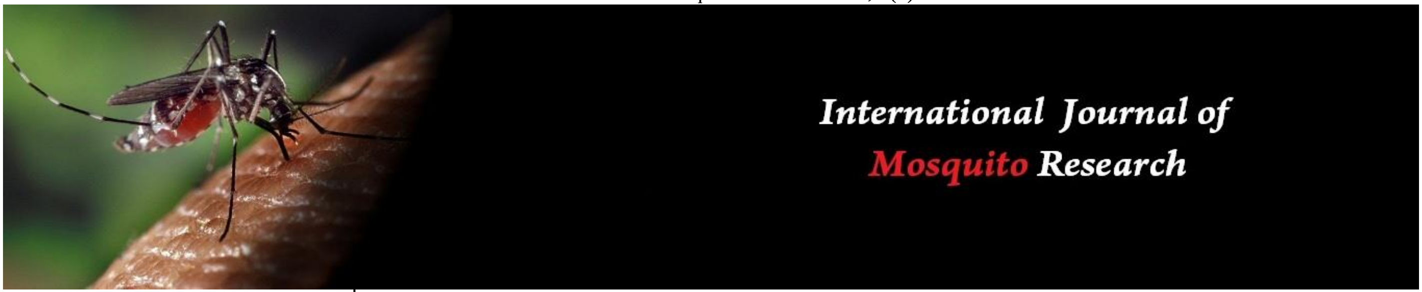

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A review on plant phytochemicals potential for mosquito control

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Abstract
Most serious diseases like malaria, yellow fever, dengue fever, chikungunya fever, filariasis, encephalitis, West Nile Virus infection, etc. are spread by mosquitoes. The use of alternate mosquito control methods was emphasized under the Integrated Mosquito Management (IMM). The The continuous utility of artificial pesticides reasons improvement of resistance in vector species, Organic magnification of poisonous substances through the food chain and adverse effects on environmental and non-target organisms which includes human fitness Since ancient times, active poisonous compounds from plant extracts have been applied as a substitute method of controlling mosquitoes. These exhibit broad-spectrum target-specific actions against several kinds of vector mosquitoes while being nontoxic, easily accessible at reasonable rates, and biodegradable. This article reviews the current state of knowledge regarding phytochemical sources and mosquitocidal activity, their mode of action on the target population, variation in their larvicidal activity according to mosquito species, instar specificity, polarity of solvents used during extraction, nature of active ingredient, and promising developments made in the biological control of mosquitoes by plant derived secondary metabolites.

Keywords: Mosquito, phytochemical, larvicidal, integrated mosquito management (IMM)

1. Introduction

Mosquitoes (Diptera: Culicidae) are the primary vectors of several deadly diseases, including malaria, filariasis, dengue fever, Japanese encephalitis, and others, in practically all tropical and subtropical nations. More than 100 species of mosquitoes have been documented to be able to infect humans with diseases, out of the approximately 3000 species of mosquitoes that have been identified globally [1]. Over 700,000,000 individuals worldwide contract mosquito-borne diseases each year, which are widespread in more than 100 nations [2]. With almost 40,000,000 people in India impacted by diseases spread by mosquitoes each year, the statistic is disturbing [3]. Mosquitoes have been dubbed "public enemy number one" by WHO. An estimated one to two million people die each year from malaria worldwide. At least 120 million people in 73 countries, including those in Africa, India, Southeast Asia, and the Pacific Islands, are said to be affected by lymphatic filariasis. According to statistics, India accounts for roughly 40 % of the world's cases of filariasis, with an estimated 720 crores in yearly economic losses [2]. The incidence of Japanese encephalitis is estimated to be between 30,000 and 50,000 per year, with a fatality rate of 10,000 [4]. In developing nations like India, mosquito-borne diseases not only have a high rate of morbidity and mortality but also significantly disrupt social order and cause significant economic loss. Mosquito management is crucial to preventing the spread of diseases transmitted by mosquitoes, as well as to enhance environmental quality and human health. Application of synthetic insecticides such as organo chlorine and organophosphate chemicals is the main instrument in mosquito control operations. However, because of operational, ecological, economic, technical, and human concerns, this has not been particularly successful. Many of the former synthetic insecticides have recently seen less use in programs to control mosquitoes. It is because there aren't enough new insecticides, synthetic insecticides are expensive, environmental sustainability is a concern, human health and other populations are negatively impacted, they aren't biodegradable, the rate of biological magnification through ecosystems is higher, and insecticide resistance is rising globally [5, 6].

Therefore, a number of laws and regulations have been developed by the Environmental Protection Act of 1969 to restrict the use of chemical control agents in nature [7]. It has led researchers to search for alternative methods, such as offering or encouraging the adoption of transparent, efficient, and public-education-focused mosquito management strategies that emphasize source reduction, monitoring, and surveillance, as well as environmentally friendly, least-toxic larval control. These issues have led to a desire to search for environmentally benign, economically viable, biodegradable, and mosquito species-specific pesticides. In light of this, the deployment of environmentally benign alternatives, such as biological vector management, has emerged as the main objective of the control program for chemical pesticides. Exploring the floral biodiversity and entering the field of employing safer insecticides of botanical origin as a direct and sustainable means of mosquito control is one of the most effective alternative approaches under the biological control strategy. Additionally, plant-derived pesticides contain botanical mixtures of chemical compounds that operate cooperatively on both behavioral and physiological processes, in contrast to conventional insecticides, which are based on a single active ingredient. Thus, the chance of pests building a resistance to such compounds is extremely low. For vector control management to remain effective, finding bio-insecticides that are effective, appropriate, and adaptable to ecological settings is essential [8].

2. Phytochemicals or bioactive compound

Botanical pesticides that are naturally occurring and derived from floral sources are called phytochemicals. Since the 1920s, phytochemicals have been used to control mosquitoes [10], but the development of synthetic insecticides like DDT in 1939 put an end to the use of phytochemicals in mosquito control programs. The decision to focus again on phytochemicals that are readily biodegradable and have no negative effects on non-target creatures was applauded after experiencing numerous issues as a result of the excessive and careless application of synthetic pesticides in nature. Since then, efforts have been made to identify the structure of new bioactive chemicals from the plant kingdom as well as to start their commercial production. Currently, phytochemicals account for up to 1 % of the global pesticide market [9].

Botanicals are basically secondary metabolites that help plants defend themselves against herbivore predators' constant selection pressure and other environmental conditions. Alkaloids, steroids, terpenoids, essential oils, and phenolics are only a few of the classes of phytochemicals from various plants that have been reported for their insecticidal properties in the past [9].

Plant extracts' insecticidal properties differ depending on the extraction method employed and the polarity of the solvents used, in addition to factors like plant and mosquito species, geographical variation, and the parts used. The extraction of mosquito poisons involved the utilization of a wide range of plants, including herbs, shrubs, and big trees. Small herbs' entire bodies as well as the numerous fruits, leaves, stems, barks, roots, and other parts of larger plants and trees were used to extract phytochemicals. For the purpose of controlling mosquitoes, the most harmful chemicals were always sought out, located, and extracted. Numerous compounds that are produced by plants, many of which have anti-inflammatory and pesticide effects. There are around 2000 plant species that are known to produce valuable chemical components and metabolites. It is known that more than 2000 plant species generate chemical components and metabolites useful in pest management programs. The plant families Solanaceae, Asteraceae, Cladophoraceae, Labiatae, Miliaceae, Oocystaceae, and Rutaceae all exhibit diverse mosquito larval, adulticidal, or repellent properties [9].

3. Integrated Mosquito Management (IMM)

To keep mosquito vector populations low, integrated mosquito management (IMM) employs a variety of techniques and tactics. It is a method for managing mosquito populations through decision-making. IMM aims to protect people from diseases spread by mosquitoes, preserve a healthy environment through responsible pesticide use and disposal, and enhance overall quality of life through practical and efficient mosquito control measures [8]. One of the tactics used by the WHO to combat tropical illnesses is the destruction of vectors or intermediary hosts. Because mosquitoes are generally immobile during the immature stage and remain more concentrated than they do in the adult form, controlling them at the larval stage is more effective and target specific than any other IMM avenues [12].

3.1 The importance of plant extracts in IMM

Insects and plants have coevolved, giving plants a variety of chemical defenses that can be utilized to repel insects [13]. More than 2000 plant species have been identified as producing secondary metabolites useful in biological pest management efforts to far, and 344 of these have been linked to considerable anti-mosquito action [14]. According to reports, representatives of the plant families Solanaceae, Asteraceae, Cladophoraceae, Labiatae, Miliaceae, Oocystaceae, and Rutaceae have larvicidal, adulticidal, or repellent effects on certain mosquito species [9]. A defense mechanism against insect and pest attacks is provided by the secondary metabolites that are found in plants. The biological activity of plant extracts against the target pest is attributed to the presence of compounds like phenolics, terpenoids, and alkaloids that act as anti-feedants, moulting hormones, oviposition deterrents, repellents, juvenile hormone mimics, growth inhibitors, anti-mounting hormones, as well as attractants. Due to their ability to regulate growth, citrus limonoids from the Rutaceae have drawn more concern [15]. Citrus compounds such as limonin, nomilin, obacunone, epilimonol, and limonin diosphenol can easily be extracted from citrus seeds, which are widely available as waste products of the citrus industry. It has been discovered that citrus limonoids can both cause toxicity and serve as a feeding deterrent. The furan ring and epoxide groups in the citrus limonoid structure have been found to be essential for the limonoid's antifeedant effect in studies of the structure-activity relationship of limonin. Limonoids cause nutritional disruption, which results in antifeedant effects and eventually affects how insects lay their eggs [16].

4. Larvicidal potential varies depending on mosquito species, plant components, and solvent based polarity

The effectiveness of phytochemicals against mosquito larvae might vary greatly depending on the plant species, plant parts employed, age of plant parts (young, mature, or senescent), extraction solvent, as well as the species of vectors that are present. Sukumar *et al.*. [17] have discussed the existence of variations in the extent to which phytochemical compounds are effective on target mosquito species relative to plant parts from which these were extracted, responses in species and their developmental stages against the specified extract, solvent of extraction, geographical origin of the plant, photosensitivity of some of the compounds in the extract, and effect on growth and reproduction.

Table 1: Efficacy of botanical extracts in controlling/reducing the population of vector mosquitoes

SL No	Solvents	Plant species	Plant parts used	Target mosquito species	References
1.	Petroleum ether solvent extract	*Artemisia annua*	Leaf	*Anopheles stephensi*	Sharma *et al.* (2006) [18]
2.	Petroleum ether solvent extract	*Acacia nilotica*	Leaf	*Anopheles stephensi*	Saktivadivel & Daniel (2008) [19]
3.	Petroleum ether solvent extract	*Argemone mexicana*	Leaf, seed	*Anopheles stephensi*	Saktivadivel & Daniel (2008) [19]
4.	Petroleum ether solvent extract	*Jatropha curcas*	Leaf	*Anopheles stephensi*	Saktivadivel & Daniel (2008) [19]
5.	Petroleum ether solvent extract	*Withania somnifera*	Leaf	*Anopheles stephensi*	Saktivadivel & Daniel (2008) [19]
6.	Petroleum ether solvent extract	*Citrullus colocynthis*	Leaf	*Anopheles stephensi*	Saktivadivel & Daniel (2008) [19]
7.	Petroleum ether solvent extract	*Aloe barbadensi*	Leaf	*Anopheles stephensi*	Maurya *et al.* (2007) [20]
8.	Petroleum ether solvent extract	*Cannabis sativa*	Leaf	*Anopheles stephensi*	Maurya *et al.* (2007) [20]
9.	Petroleum ether solvent extract	*Eucalyptus globules*	Seed, leaf	*Culex pipiens*	Sheeren *et al.* (2006) [21]
10.	Petroleum ether solvent extract	*Solanum xanthocarpum*	Root	*Cx. pipiens pallens*	Mohan *et al.* (2006) [22]
11.	Petroleum ether solvent extract	*Thymus capitatus*	Leaf	*Cx. pipiens*	Mansour *et al.* (2000) [17]
12.	Petroleum ether solvent extract	*Citrus aurantium*	Fruit peel	*Cx. quinquefasciatus*	Kassir (1989) [23]
13.	Petroleum ether solvent extract	*Myrtus communis*	Flower and Leaf	*Cx. pipiens molestus*	Traboulsi *et al.* (2002) [24]
14.	Petroleum ether solvent extract	*Origanum syriacum*	Leaf	*Cx. pipiens molestus*	Traboulsi *et al.* (2002) [19]
15.	Petroleum ether solvent extract	*Mentha microcorphylla*	Leaf	*Cx. pipiens molestus*	Traboulsi *et al.* (2002) [24]
16.	Petroleum ether solvent extract	*Pistacia lentiscus*	Leaf	*Cx. pipiens molestus*	Traboulsi *et al.* (2002) [24]
17.	Petroleum ether solvent extract	*Lavandula stoechas*	Leaf	*Cx. pipiens molestus*	Traboulsi *et al.* (2002) [24]
18.	Petroleum ether solvent extract	*Jatropha curcas*	Leaf	*Cx. quinquefasciatus*	Rahuman *et al.* (2007) [26]
19.	Petroleum ether solvent extract	*Pedilanthus tithymaloides*	Leaf	*Cx. quinquefasciatus*	Rahuman *et al.* (2007) [26]
20.	Petroleum ether solvent extract	*Phyllanthus amarus*	Leaf	*Cx. quinquefasciatus*	Rahuman *et al.* (2007) [26]
21.	Petroleum ether solvent extract	*Argemone mexicana*	Leaf	*Cx. quinquefasciatus*	Karmegan *et al.* (1996) [25]
22.	Petroleum ether solvent extract	*Jatropha curcus*	Leaf	*Cx. quinquefasciatus*	Karmegan *et al.* (1996) [25]
23.	Petroleum ether solvent extract	*Pergularia extensa*	Leaf	*Cx. quinquefasciatus*	Karmegan *et al.* (1996) [25]
24.	Petroleum ether solvent extract	*Withania somnifera*	Leaf	*Cx. quinquefasciatus*	Karmegan *et al.* (1996) [25]
25.	Petroleum ether solvent extract	*Piper nigrum*	Seed	*Cx. pipiens*	Shaalan *et al.* (2005) [9]
26.	Petroleum ether solvent extract	*Euphorbia hirta*	Stem bark	*Cx. quinquefasciatus*	Rahuman *et al.* (2007) [26]
27.	Petroleum ether solvent extract	*E. tirucalli*	Stem bark	*Cx. quinquefasciatus*	Rahuman *et al.* (2007) [26]
28.	Petroleum ether solvent extract	*Ocimum basilicum*	Leaf	*An. stephensi and Cx. quinquefasciatus*	Maurya *et al.* (2009) [27]
29.	Hexane solvent extract	*Momordica charantia*	Fruit	*An. stephensi*	Singh *et al.* (2006) [28]
30.	Hexane solvent extract	*Momordica charantia*	Fruit	*Cx. quinquefasciatus*	Singh *et al.* (2006) [28]
31.	Hexane solvent extract	*Momordica charantia*	Fruit	*Ae. aegypti*	Singh *et al.* (2006) [28]
32.	Hexane solvent extract	*Kaempferia galanga*	Rhizome	*Cx. quinquefasciatus*	Choochote *et al.* (1999) [29]
33.	Hexane solvent extract	*Khaya senegalensis*	Leaf	*Cx. annulirostris*	Shaalan *et al.* (2005) [9]
34.	Hexane solvent extract	*Daucus carota*	Leaves	*Cx. annulirostris*	Shaalan *et al.* (2005) [99]
35.	Hexane solvent extract	*Curcuma aromatica*	Rhizome	*Ae. aegypti*	Choochate *et al.* (2005) [30]
36.	Hexane solvent extract	*Cybistax antisyphilitica*	Stem wood	*Ae. aegypti*	Rodrigues *et al.* (2005) [27]
37.	Hexane solvent extract	*Eucalyptus citriodora*	Leaf	*An. stephensi, Cx. Quinque - fasciatus, Ae. aegypti*	Singh *et al.* (2007) [32]
38.	Hexane solvent extract	*Solanum nigrum*	Dried fruit	*An. Culicifacies, An Stephensi, Cx. Quinque-fasciatus, Ae. aegypti*	Raghavendra *et al.* (2009) [33]
39.	Acetone solvent extract	*Tridax procumbens*	Leaf	*An. subpictus*	Kamaraj *et al.* (2011) [34]
40.	Acetone solvent extract	*Ageratum conyzoides*	Leaf	*Cx. quinquefasciatus*	Saxena *et al.* (1992) [35]
41.	Acetone solvent extract	*Cleome icosandra*	Leaf	*Cx. quinquefasciatus*	Saxena *et al.* (1992) [35]
42.	Acetone solvent extract	*Tridax procumbens*	Leaf	*Cx. quinquefasciatus*	Saxena *et al.* (1992) [35]
43.	Acetone solvent extract	*Ageratina adenophora*	Twigs	*Ae. aegypti and Cx. quinquefasciatus*	Raj Mohan & Ramaswamy (2007) [36]
44.	Acetone solvent extract	*Feronia limonia*	Leaf	*Cx. Quinquefasciatus, An. stephensi, Ae. aegypti*	Rahuman *et al.* (2000) [37]
45.	Acetone solvent extract	*Millingtonia hortensis*	Leaf	*An. stephensi, Ae. aegypti and Cx. quinquefasciatus*	Kaushik & Saini (2008) [38]
46.	Acetone solvent extract	*O. sanctum*	Leaf	*Ae. aegypti, Cx. quinquefasciatus*	Anees (2008) [39]
47.	Carbon tetra chloride solvent extract	*Aloe barbadensis*	Leaf	*An. stephensi*	Maurya *et al.* (2007) [27]
48.	Carbon tetra chloride solvent extract	*S. xanthocarpum*	Root	*Cx. pipiens pallens*	Mohan *et al.* (2006) [22]
49.	Carbon tetra chloride solvent extract	*E. globulus*	Seed and leaf	*Cx. pipiens*	Sheeren (2006) [21]
50.	Chloroform extract	*Plumbago zeylanica, P. dawei and P. stenophylla*	Root	*An. gambiae*	Maniafu *et al.* (2009) [40]
51.	Chloroform extract	*Euphorbia tirucalli*	Latex and stem bark	*Cx. pipiens pallens*	Yadav *et al.* (2002) [41]
52.	Chloroform extract	*Nyctanthes arbortristis*	Flower	*Cx. quinquefasciatus*	Khatune *et al.* (2001) [42]
53.	Chloroform extract	*Citrus sinensis*	Fruit peel	*An. subpictus*	Bagavan *et al.* (2009) [43]
54.	Chloroform extract	*Aloe ngongensis*	Leaf	*An. gambie*	Matasyoh *et al.* (2008) [44]
55.	Chloroform extract	*Millettia dura*	Seed	*Ae. aegypti*	Yenesew *et al.* (2003) [45]
56.	Chloroform extract	*Cassia obtusifolia*	Seed	*Ae. Aegypti, Ae. togoi, and Cx.*	Yang *et al.* (2003) [46]

				pipiens pallens	
57.	Methanol extract	*Atlantia monophylla*	Leaf	*An. stephensi*	Sivagnaname & Kalyanasundaram (2004) [47]
58.	Methanol extract	*Dysoxylum Malabaricum*	Leaf	*An. stephensi*	Senthil Nathan *et al.* (2006) [48]
59.	Methanol extract	*Melia azedarach*	Leaf and seeds	*An. stephensi*	Senthil Nathan *et al.* (2006) [48]
60.	Methanol extract	*Moringa oleifera*	Bark	*Cx. gelidus*	Kamaraj & Rahuman (2010) [52]
61.	Methanol extract	*Ocimum gratissimum*	Leaf	*Cx. gelidus*	Kamaraj & Rahuman (2010) [52]
62.	Methanol extract	*Solenostemma argel*	Aerial parts	*Cx. pipens*	Al-Doghairi *et al.* (2004) [47]
63.	Methanol extract	*S. xanthocarpum*	Root	*Cx. pipiens pallens*	Mohan *et al.* (2006) [22]
64.	Methanol extract	*Chrysanthemum indicum*	Leaf	*Cx. tritaeniorhynchus*	Kamaraj *et al.* (2010) [50]
65.	Methanol extract	*Azadirachta indica*	Leaf	*Cx. pipens*	El Hag *et al.* (1999) [65]
66.	Methanol extract	*Rhazya stricta*	Leaf	*Cx. pipens*	El Hag *et al.* (1999) [65]
67.	Methanol extract	*Momordica charantia*	Leaf	*Cx. quinquefasciatus*	Prabakar & Jebanesan (2004) [49]
68.	Methanol extract	*Trichosanthes anguina*	Leaf	*Cx. quinquefasciatus*	Prabakar & Jebanesan (2004) [49]
69.	Methanol extract	*Luffa acutangula*	Leaf	*Cx. quinquefasciatus*	Prabakar & Jebanesan (2004) [49]
70.	Methanol extract	*Benincasa cerifera*	Leaf	*Cx. quinquefasciatus*	Prabakar & Jebanesan (2004) [49]
71.	Methanol extract	*Citrullus vulgaris*	Leaf	*Cx. quinquefasciatus*	Prabakar & Jebanesan (2004) [49]
72.	Methanol extract	*Vitex negundo*	Leaf	*Cx. quinquefasciatus*	Krishnan *et al.* (2007) [50]
73.	Methanol extract	*V. trifolia*	Leaf	*Cx. quinquefasciatus*	Krishnan *et al.* (2007) [50]
74.	Methanol extract	*V. peduncularis*	Leaf	*Cx. quinquefasciatus*	Krishnan *et al.* (2007) [50]
75.	Methanol extract	*V. altissima*	Leaf	*Cx. quinquefasciatus*	Krishnan *et al.* (2007) [50]
76.	Methanol extract	*Centella asiatica*	Leaf	*Cx. quinquefasciatus*	Rajkumar & Jebanesan (2005) [51]
77.	Methanol extract	*Euphorbia tirucalli*	Latex and stem bark	*Cx. pipiens pallens*	Yadav *et al.* (2002) [42]
78.	Methanol extract	*Eucalyptus globulus*	Seed and leaf	*Cx. Pipiens*	Sheeren (2006) [21]
79.	Methanol extract	*Atlantia monophylla*	Leaf	*Cx. Quinquefasciatus*	Sivagnaname & Kalyanasundaram (2004) [47]
80.	Methanol extract	*Pavonia zeylanica*	Leaf	*Cx. Quinquefasciatus*	Vahitha *et al.* (2002) [56]
81.	Methanol extract	*Acacia ferruginea*	Leaf	*Cx. Quinquefasciatus*	Vahitha *et al.* (2002) [56]
82.	Methanol extract	*Coccinia indica, Cucumus sativus, Momordica charantia*	Leaf	*Cx. Quinquefasciatus and Ae. aegypti*	Rahuman & Venkatesan (2008) [26]
83.	Methanol extract	*Cassia tora*	Seed	*Ae. aegypti and Cx. pipiens pallens*	Jang *et al.* (2002) [57]
84.	Methanol extract	*Atlantia monophylla*	Leaf	*Ae. Aegypti*	Sivagnaname & Kalyanasundaram (2004) [47]
85.	Methanol extract	*Coccinia indica, Cucumis sativus, Momordica charantia*	Leaf	*Ae. Albopictus*	Rahuman & Venkatesan (2008) [26]
86	Methanol extract	*Aristolochia saccata*	Root	*Ae. Albopictus*	Das *et al.* (2007) [58]
87.	Methanol extract	*Annona squamosa*	Leaf	*Ae. Albopictus*	Das *et al.* (2007) [58]
88.	Methanol extract	*Gymnopetelum cochinchinensis*	Fruit/ pericarp	*Ae. Albopictus*	Das *et al.* (2007) [58]
89.	Methanol extract	*Caesalpinea sp.*	Bark	*Ae. Albopictus*	Das *et al.* (2007) [58]
90.	Methanol extract	*Piper sp.*	Stem	*Ae. Albopictus*	Das *et al.* (2007) [58]
91.	Methanol extract	*Chamaecyparis obtusa*	Leaf	*An. Stephensi*	Jang *et al.* (2005) [59]
92.	Methanol extract	*Acalypha alnifolia*	Leaf	*An. stephensi, Ae. aegypti and Cx. quinquefasciatus*	Kovendan *et al.* (2012) [60]
93.	Chloroform: methanol extract (1:1)	*Solanum villosum*	Leaf	*An. Subpictus*	Chowdhury *et al.* (2009) [61]
94.	Chloroform: methanol extract (1:1)	*Cestrum diurnum*	Leaf	*An. Stephensi*	Ghosh & Chandra (2006) [62]
95.	Chloroform: methanol extract (1:1)	*Cestrum diurnum*	Leaf	*Cx. Quinquefasciatus*	Ghosh *et al.* (2008) [63]
96.	Chloroform: methanol extract (1:1)	*Solanum villosum*	Berry	*Ae. Aegypti*	Chowdhury *et al.* (2008) [61]
97.	Ethanol Extract	*Cassia obtusifolia*	Leaf	*An. Stephensi*	Rajkumar & Jebanesan (2009) [65]
98.	Ethanol Extract	*Azadirachta indica*	Leaf	*Cx. Fatigans*	Azmi *et al.* (1998) [66]
99.	Ethanol Extract	*Piper retrofractum*	Unripe and ripe fruit	*Cx. Quinquefasciatus*	Chansang *et al.* (2005) [67]
100.	Ethanol Extract	*Citrus reticulata*	Seed	*Cx. quinquefasciatus and Ae. aegypti*	Sumroiphon *et al.* (2006) [68]
101.	Ethanol Extract	*Azadirechta indica*	Leaf	*Ae. Aegypti*	Mgbemena (2010) [69]
102.	Ethanol Extract	*Azadirechta indica, Ocimum gratissimium and Citrus citratus*	Leaf	*Ae. Aegypti*	Mgbemena (2010) [69]
103.	Ethanol Extract	*Apium graveolens*	Seed	*Ae. Aegypti*	Choochate *et al.* (2004) [70]
104.	Ethanol Extract	*Rhizophora mucronata*	Bark, pith, stem wood	*Ae. Aegypti*	Kabaru & Gichia (2001) [71]
105.	Ethanol Extract	*Piper longum*	Fruit exocarp	*Ae. Aegypti*	Chaithong *et al.* (2006) [72]
106.	Ethanol Extract	*P. ribesoides*	Fruit exocarp	*Ae. Aegypti*	Chaithong *et al.* (2006) [72]
107.	Ethanol Extract	*P. sarmentosum*	Fruit exocarp	*Ae. Aegypti*	Chaithong *et al.* (2006) [72]
108.	Ethanol Extract	*Annona crassiflora*	Root wood	*Ae. Aegypti*	Omena *et al.* (2007) [73]
109.	Ethanol Extract	*Annona crassiflora*	Root bark	*Ae. Aegypti*	Omena *et al.* (2007) [73]
110.	Ethanol Extract	*Annona crassiflora*	Stem	*Ae. Aegypti*	Omena *et al.* (2007) [73]
111.	Ethanol Extract	*A. glabra*	Seed	*Ae. Aegypti*	Omena *et al.* (2007) [73]
112.	Ethanol Extract	*A. muricata*	Root	*Ae. Aegypti*	Omena *et al.* (2007) [73]
113.	Ethanol Extract	*A. squamosa*	Root	*Ae. Aegypti*	Omena *et al.* (2007) [73]
114.	Ethanol Extract	*A. squamosa*	Leaf	*Ae. Aegypti*	Omena *et al.* (2007) [73]

115.	Ethanol Extract	*Denis sp.*	Root	*Ae. Aegypti*	Omena *et al.* (2007) [73]
116.	Ethanol Extract	*Erythrina mulungu*	Stem bark	*Ae. Aegypti*	Omena *et al.* (2007) [73]
117.	Ethanol Extract	*Pterodon polygalaeflorus*	Seed	*Ae. Aegypti*	Omena *et al.* (2007) [73]
118.	Ethanol Extract	*Tagetes minuta*	Aerial parts	*Ae. Fluviatilis*	Macedo *et al.* (1997) [74]
119.	Ethanol Extract	*Eclipta paniculata*	Aerial parts	*Ae. Fluviatilis*	Macedo *et al.* (1997) [74]
120.	Benzene extract	*Citrullus vulgaris*	Leaf	*Ae. Stephensi*	Mullai *et al.* (2008) [75]
121.	Benzene extract	*Acalypha indica*	Leaf	*Ae. Stephensi*	Govindarajan *et al.* (2008) [76]
122.	Benzene extract	*C. vulgaris*	Leaf	*Ae. Aegypti*	Mullai *et al.* (2008) [75]
123.	Ethyl acetate extract	*Dysoxylum malabaricum*	Leaf	*An. Stephensi*	Senthil Nathan *et al.* (2008) [78]
124.	Ethyl acetate extract	*D. beddomei Aloe turkanensis*	Leaf	*An. Gambiae*	Matasyoh *et al.* (2008) [44]
125.	Ethyl acetate extract	*Solanum nigrum*	Leaf	*Cx. Quinquefasciatus*	Rawani *et al.* (2010) [79]
126.	Ethyl acetate extract	*Ocimum gratissimum*	Leaf	*Cx. gelidus and Cx. quinquefasciatus*	Kamaraj & Rahuman (2010) [50]
127.	Ethyl acetate extract	*Annona squamosa*	Bark	*Cx. quinquefasciatus and An. stephensi*	Kamaraj *et al.* (2010) [50]
128.	Ethyl acetate extract	*O. sanctum*	Leaf	*Ae. aegypti, Cx. quinquefasciatus*	Anees (2008) [39]
129.	Aqueous extract	*Carica papaya*	Seed	*Cx. Quinquefasciatus*	Rawani *et al.* (2009) [79]
130.	Aqueous extract	*Murraya paniculata*	Fruit	*Cx. Quinquefasciatus*	Rawani *et al.* (2009) [79]
131.	Aqueous extract	*Cleistanthus collinus*	Leaf	*Cx. Quinquefasciatus*	Rawani *et al.* (2009) [79]
132.	Aqueous extract	*Cleistanthus collinus*	Leaf	*An. Gambiae*	Rawani *et al.* (2009) [79]
133.	Aqueous extract	*Hemidesmus indicus*	Root	*Cx. Quinquefasciatus*	Khanna & Kannabiran (2007) [81]
134.	Aqueous extract	*Gymnema sylvestre*	Leaf	*Cx. Quinquefasciatus*	Khanna & Kannabiran (2007) [81]
135.	Aqueous extract	*Eclipta prostrata*	Leaf, root	*Cx. Quinquefasciatus*	Khanna & Kannabiran (2007) [81]
136.	Aqueous extract	*Artimisia cina*	Leaf	*Cx. Pipens*	Aly & Bardan (1986) [82]
137.	Aqueous extract	*Cleome droserifolia*	Leaf	*Cx. Pipens*	Aly & Bardan (1986) [82]
138.	Aqueous extract	*Piper retrofractum*	Un ripe and ripe fruit	*Cx. Quinquefasciatus and Ae. aegypti*	Chansang *et al.* (2005) [67]
139.	Aqueous extract	*Solanum villosum*	Leaf	*An. stephensi, Cx. quinquefasciatus and Ae. aegypti*	Chowdhury *et al.* (2008) [83]
140.	Aqueous extract	*Solanum nigrum*	Dried fruit	*An. culicifacies species A, An. culicifacies species C, An. stephensi, Cx. quinquefasciatus and Ae. aegypti*	Raghavendra *et al.* (2009) [33]
141.	Steam distillation	*Paullinia clavigera*	Leaf	*An. Benarrochi*	Iannacone & Pérez (2004) [84]
142.	Steam distillation	*Tradescintia zebrina*	Leaf	*An. Benarrochi*	Iannacone & Pérez (2004) [84]

5. The nature of the active components that cause larval toxicity

The world of plants contains a vast, untapped reservoir of phytochemicals that could be widely utilized in mosquito control programs in place of industrial insecticides. Alkanes, alkenes, alkynes, and simple aromatics, lactones, essential oils, fatty acids, terpenes, alkaloids, steroids, is flavonoids, pterocarpines, and lignans are examples of secondary materials derived from plants that have the potential to kill mosquito larvae. (Kishore *et al.* [2007] [85] reviewed the effectiveness of phytochemicals against mosquito larvae according to their chemical nature. Additionally, they reported on the isolation of numerous bioactive toxic components from a variety of plants and their toxicity toward diverse mosquito species.

6. Mode of action of phytochemicals in target insect body

Secondary metabolites that have evolved to defend plants from herbivores typically make up the poisonous active components in plant extracts. These secondary metabolites may expose the insects to poisonous compounds that have relatively non-specific effects on a variety of molecular targets as they are consumed by the insects. These targets include proteins (including structural proteins, enzymes, receptors, signaling molecules, ion channels, and receptors), nucleic acids, bio membranes, and other cellular components [86]. The principal result of this is abnormality in the nervous system (such as, in neurotransmitter synthesis, storage, release, binding, and re-uptake, receptor activation and function, enzymes involved in signal transduction pathway), which in turn affects insect physiology in many different ways and at various receptor sites. n a review of the mechanism of action of plant secondary metabolites on insect bodies, Rattan [86] noted several physiological disruptions, including the inhibition of acetyl cholinesterase (by essential oils), GABA-gated chloride channels (by thymol), disruption of sodium and potassium ion exchanges (by pyrethrin), and the inhibition of cellular respiration. This disruption also includes hormonal imbalance, mitotic poisoning (azadirachtin), disruption of the molecular events of morphogenesis, alteration in the behavior and memory of the cholinergic system (by essential oil), blockage of calcium channels (by ryanodine), blockage of nerve cell membrane action (by sabadilla), blockage of octopamine receptors (by thymol), etc. The suppression of acetyl cholinesterase activity (AChE), which is a crucial enzyme involved in stopping the transmission of nerve impulses along synaptic pathways, is the most significant of these activities; It is well known that the modification in AChE is one of the key resistance mechanisms in insect pests, and that it is resistant to carbamates and organ phosphorus [87].

7. Conclusion

A global issue involving mosquitoes as carriers of some of the most serious disease-causing pathogens necessitates collaboration across all working groups under one overarching initiative in order to avoid repeating trials and tests and to produce some useful results soon. It is challenging to compare the repellency results from various bioassays due to the varying test circumstances, lack of homogeneity in bioassays, absence of standard materials, and fundamental assumptions associated with each bioassay system. Phytochemicals currently account for 1 % of the global pesticide market. For the control of mosquito-borne diseases, it is essential to identify, isolate, and mass-produce bioactive chemicals of plant origin. The positive outcomes of early studies on the ability of plant extracts to repel mosquitoes encourage further research into the bioactive substances found in those extracts that may be effective larvicidal agents when isolated in pure form, according to the International Journal of Mosquito Research. Additionally, there is a need for time-tested drug delivery systems for active ingredients derived from plants. Finding plant-based insecticides that are effective, suitable for and adaptable to local ecological conditions, biodegradable, and have the widespread mosquitocidal characteristic will work as a new weapon in the insecticides' armory and help reduce the use of harmful chemicals.

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