PLANT SCIENCE TODAY
Vol x(x): xx–xx
https://doi.org/10.14719/pst.3323

eISSN 2348-1900

REVIEW ARTICLE

Natural compounds as mosquito larvicides: A comprehensive review

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Received: 02 February 2025; Accepted: 19 March 2025; Available online: Version 1.0: 23 July 2025

Cite this article: Anamika KS, Manikantan P. Natural compounds as mosquito larvicides: A comprehensive review. Plant Science Today (Early Access). https:/doi.org/10.14719/pst.3323

Abstract

As a tropical country, India is a fertile breeding ground for mosquitoes, leading to more than 7 lakh deaths annually. The need to control their widespread use was essential globally, leading to chemical usage. Synthetic insecticides used in chemical control methods have been preferred since the previous era due to their spontaneous effect and ease of application. However, it has now been recognized that chemical insecticides and larvicides cannot be utilized for vector control on the same scale due to many known and unknown causes. The problems, ranging from general skin irritation to severe deadly issues such as genetic disorders, have been reported. The mosquito population is increasing daily due to many factors, such as environmental pollution, water quality, global warming and so on, which are causing detrimental effects; however, these are interconnected, which worsens the scenario. Even though undeveloped countries suffer from those mentioned above, cost-effective eradication is a topic to be interrogated. Hence, they follow and use cheap chemicals common in the market, leading to environmental pollution. Therefore, it is necessary to investigate the possible efficacy of biologically active plant extracts to lessen pollution and lower expenditure. This review examines 30 plants from 10 families, highlighting their effects on mosquito larvae and potential use in controlling mosquito populations.

Keywords: fabaceae; lamiaceae; LC50; leguminosae; malvaceae; mosquito larvicidal; myrtaceae; piperaceae; plant extracts; rubiaceae; solanaceae; verbenaceae; zingiberaceae.

Introduction

Among the most serious health issues that humanity is currently dealing with are filariasis, dengue fever, yellow fever, malaria and many others that are spread mainly by mosquitoes. Mosquitoes constitute the most significant vectors facilitating the transmission of viruses and parasites, negatively impacting all life forms. Considering they are disease-carrying vectors, some species belonging to the genera *Anopheles, Aedes* and *Culex* play a significant role in poverty and social degradation. Mosquitoes showcase cosmopolitan distribution but are attracted to tropical and subtropical areas. As a tropical country, India is a fertile breeding ground for mosquitoes, leading to more than 7 lakh deaths annually (1). In India, 415 of 3563 species were identified, with *Anopheles*, *Culex* and *Aedes* being the protagonists (2). The death caused by malaria and dengue alone exceeds 4.5 lakhs, but Japanese encephalitis acts as the fatal one due to the rampant nature and high mortality in children. Due to specific factors like global warming *Anopheles* (malaria), *Culex* (filariasis, Japanese encephalitis) and *Aedes* (dengue, zika, chikungunya) spread the disease profoundly (1).

One strategy for managing the diseases spread by mosquitoes is either by eliminating the vector, using repellents to stop mosquito bites, or massively killing the larvae at the vector's breeding grounds. The continuous application of insect growth regulators and organophosphates is essential for controlling mosquito larvae globally. These issues have brought attention to the need for fresh approaches to managing them. Synthetic insecticides have regularly suppressed mosquito populations, disturbed the natural biological control systems and allowed mosquito populations to recover. Additionally, it has led to resistance, ecological imbalance, harm to humans and animals and unfavorable effects on non-targeted organisms (3). For example, insecticides like pyrethroids led to the emergence of resistant strains like *An. minimus sensu lato*, *An. dirus*, *An. epiroticus,* which were uncontrollable. These expensive and concern-raising substances can cause irritation, breathing issues and chronic endocrine and neurological complications (2). Therefore, an eco-friendly and cost-effective alternative must be devised, highlighting the significance of phytochemicals.

Using botanicals, which are widely biodegradable, non-toxic and exhibit broad-spectrum, target-specific activity, is an option to prevent the adverse effects of chemical larvicides. One less expensive and environmentally friendly method of controlling mosquito larvae is using phytochemicals found in plant oils, leaves and roots. These chemicals are used to control mosquitoes during their larval stage of development. Because of their exceptional larvicidal, pupicidal and adulticidal qualities, phytochemicals with mosquitocidal potential are now acknowledged as strong substitutes for synthetic insecticides in mosquito control programs. Certain naturally occurring plant compounds can create novel insecticides and repellents. Meanwhile, humanity can rely on them because the botanical chemical derivatives are less environmentally harmful (3, 4) (Fig. 1 & 2).

This review focuses mainly on 10 different plant families (Fabaceae, Lamiaceae, Leguminosae, Malvaceae, Myrtaceae, Piperaceae, Rubiaceae, Solanaceae, Verbanaceae and Zingiberaceae) and the effect of 3 plants from each family, as outlined in table 1 (Fig. 3, 4, 5, & 6). It discusses the impact of these plants on different mosquito larvae as detailed in table 2.

Methodology

A preliminary search was conducted using Google Scholar to identify patterns and availability of plants associated with mosquito mortality. Based on availability and existing literature, ten native plant families were selected and efforts were made to identify three representative plants from each family. Relevant research articles for each plant were collected primarily through Google Scholar, with occasional use of Sci-Hub for easier access to certain papers. Priority was given to research articles to ensure data accuracy and minimize errors. To ensure authenticity and maintain proper documentation standards, all plant photographs were captured using the GPS Map Camera app, which embeds location metadata directly into the images, thereby reducing the risk of plagiarism and addressing potential copyright concerns. In addition to the field photographs, other scientific illustrations were created using BioRender, which ensured both original and of high professional standard, thereby enhancing the clarity and overall impact of the study.

Results

Fabaceae

Delonix elata: White gulmohar is a large tree with white flowers and compound leaves that are seasonal and common throughout South India and almost all Asian countries. The leaves and seeds show larvicidal activity but exhibit low potency. The LC50 values are 93.59 ppm and 111.83 ppm for *An. stephensi* and *A. aegypti* for methanol extraction, respectively (5). *Cx. quinquefasciatus* is also prone to the *Delonix elata* extract with an LC50 of 124.84 mg/L and 147.86 mg/l for leaves and seed, respectively. 100% mortality was exhibited at 375 mg/L and the methanolic extract was effective for ovicidal activity (6).

Psoralea corylifolia : *P. corylifolia,* a herbaceous perennial that is common in semi-arid regions such as China, Eastern and Central India and so on, grows to 125 cm. Due to its abundance, it is considered a wild plant even though it has certain medicinal properties. A study reported that *Psoralea* has larvicidal activity against *Cx. quinquefasciatus* with a value of 63.38± 6.30 ppm (LC50) (7).

In another experiment, the aqueous extract showed LC50 at 699.915 ppm; ethanolic extract showed LC50 at 66.71 ppm, whereas petroleum ether fraction was 26 ppm. When comparing petroleum-ether, ethanol and aqueous, the petroleum-ether extract displayed a higher fatality risk at lower doses. Thus, the study suggests that *Psoralea* may potentially decimate mosquito larvae and it is relevant for developing as a safer larvicide (8).

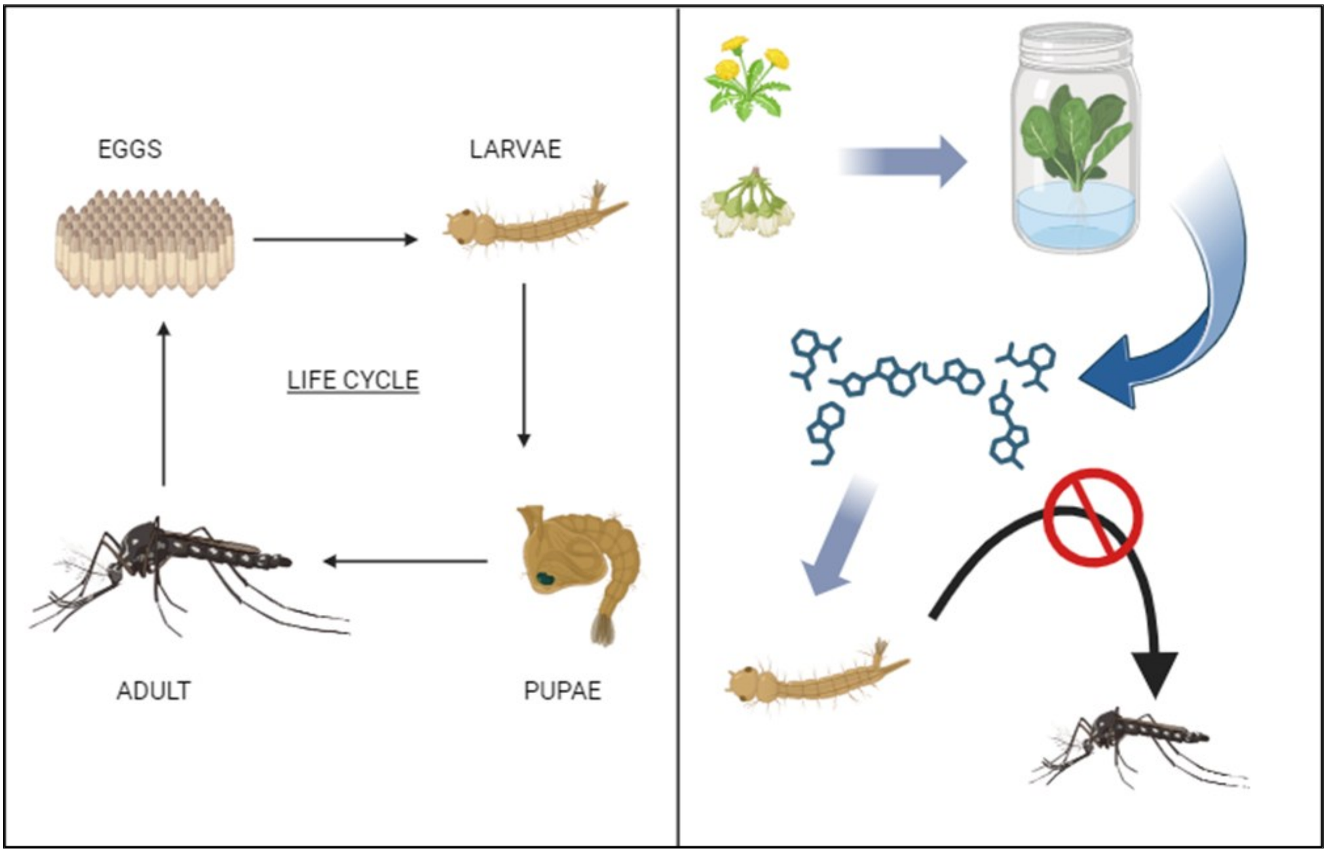

Fig. 1. Normal life cycle of mosquito larva and changes induced by plant chemicals.

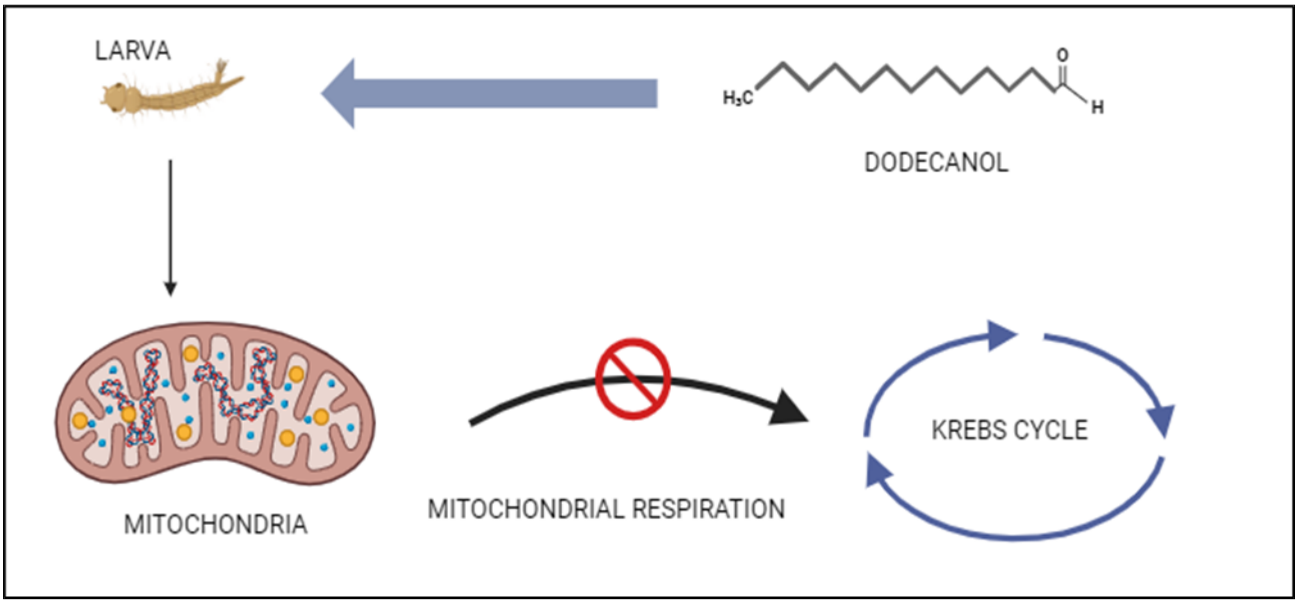

Fig. 2. Action of dodecanol on mosquito larva.

Table 1. Plants with family, common name and biomarkers

Sl. No	Genus and species	Common Name	Family	Biomarkers	References
1	*Delonix elata*	White gulmohar	Fabaceae	Quercetin, rutin, luteolin	5, 6
2	*Psorlea corylifolia*	Babchi	Fabaceae	Psoralidin, bakuchiol	7, 8
3	*Tamarindus indica*	Tamarind tree	Fabaceae	Luteolin, apigenin, catechins, epicatechins, quercetin, isorhamnetin	9
4	*Leucas aspera*	Thumbai	Lamiaceae	Rutin, baicalein, procyanidin	10, 11
5	*Clerodendron viscosum*	Hill glory bower	Lamiaceae	Quercetin, apigenin, kaempferol	12, 13, 14
6	*Mentha piperita*	Mint	Lamiaceae	Menthol, menthone, pulegone	15, 16
7	*Bauhinia variegate*	Orchid tree	Leguminosae	Quercetin, prunin, kaempferol	17, 18
8	*Cassia fistula*	Golden shower	Leguminosae	Quercetin, rutin, kaempferol	19, 20
9	*Cassia auriculata*	Tanner's cassia	Leguminosae	Quercetin, kaempferol, catechin, epigallocatechin	21, 22
10	*Hibiscus sabdariffa*	Roselle	Malvaceae	Quercetin, kaempferol, anthocyanin	23, 24
11	*Sida acuta*	Common wireweed	Malvaceae	Quercetin, rutin, kaempferol	25, 26
12	*Corchorus capsularis*	White jute	Malvaceae	Quercetin, rutin, kaempferol	27
13	*Syzygium aromaticum*	Cloves	Myrtaceae	Quercetin, kaempferol, eugenol, acetyleugenol	28, 29, 30
14	*Eucalyptus teriticornis*	Eucalyptus	Myrtaceae	Quercetin, rutin, kaempferol	31, 32
15	*Callistemon rigidus*	Weeping bottle brush	Myrtaceae	Piceatannol, scirpusin B	33
16	*Piper nigrum*	Pepper	Piperaceae	Piperine, quercetin, kaempferol	34, 35
17	*Piper betle*	Betel vine	Piperaceae	Eugenol, caryophyllene, chavibetol acetate	36, 37
18	*Piper longum*	Indian long pepper	Piperaceae	Piperine, guineesine	38, 39
19	*Morinda citrifolia*	Indian mulberry	Rubiaceae	Scopoletin, rubiadin, deacetylasperulosidic acid	40, 41
20	*Tarenna asiatica*	Asiatic tarenna tharani	Rubiaceae	Rutin, epicatechin	42, 43
21	*Neolamarckia cadamba*	Common bur-flower	Rubiaceae	Rutin, epicatechin	44, 45
22	*Solanum nigrum*	Black nightshade	Solanaceae	Solasonine, solamargine, quercetin, kaempferol	46, 47
23	*Datura stramonium*	Jimsonweed	Solanaceae	Scopolamine, hyoscyamine	48, 49
24	*Nicotiana tabacum*	Tobacco	Solanaceae	Nicotine, nicotinamide, nicotianamine, nicotinamide riboside	50, 51
25	*Lantana camara*	Common lantana	Verbenaceae	Lantadenes, quercetin, kaempferol	52, 53
26	*Vitex negundo*	Horse shoe vitex	Verbenaceae	Vitedoin, chlorogenic acid, protocatechuic acid	54, 55, 56
27	*Aloysia citrodora*	Lemon bee brush	Verbenaceae	Caffeic acid, rosmarinic acid, apigenin, luteolin	57, 58
28	*Hedychium coronarium*	White ginger lily	Zingiberaceae	Citral, geraniol, linalool	59, 60
29	*Zingiber officinale*	Ginger	Zingiberaceae	Shogaols, gingerols, zingerone	61, 62
30	*Curcuma longa*	Turmeric	Zingiberaceae	Curcumin, demethoxycurcumin, bisdemethoxycurcumin	63, 64

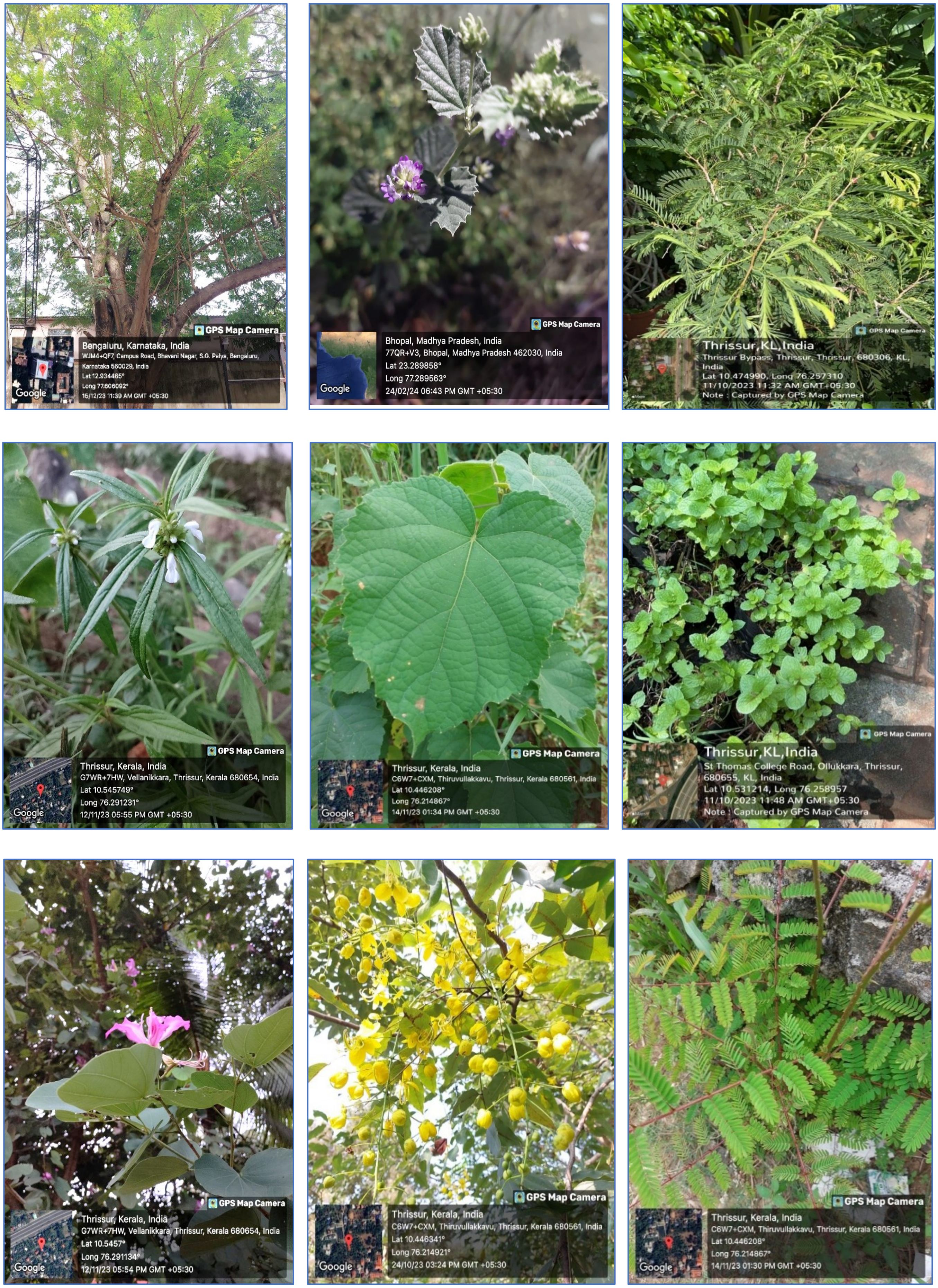

Fig. 3. Pictorial representation of plants used as larvicides.

(a) *Delonix elata* ; (b) *Psorlea corylifolia* ; (c) *Tamarindus indica*; (d) *Leucas aspera* ; (e) *Clerodendron viscosum*; (f) *Mentha piperita* ; (g) *Bauhinia variegate* ; (h) *Cassia fistula* ; (i) *Cassia auriculata*

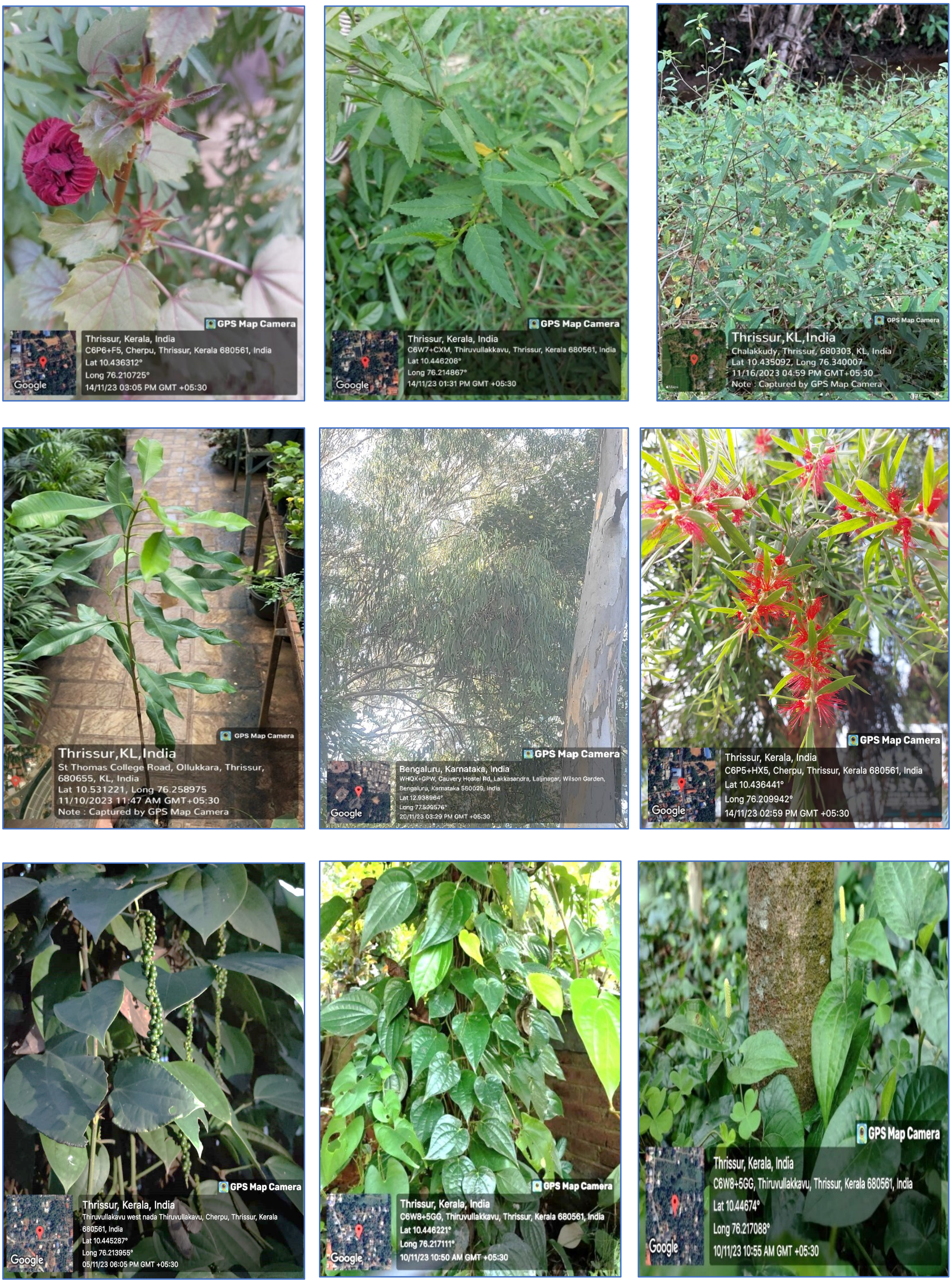

Fig. 4. Pictorial representation of plants used as larvicides.

(a) *Hibiscus sabdariffa* ; (b) *Sida acuta* ; (c) *Corchorus capsularis* ; (d) *Syzygium aromaticum* ; (e) *Eucalyptus teriticornis* ; (f) *Callistemon rigidus* ; (g) *Piper nigrum* ; (h) *Piper betle* ; (i) *Piper longum*

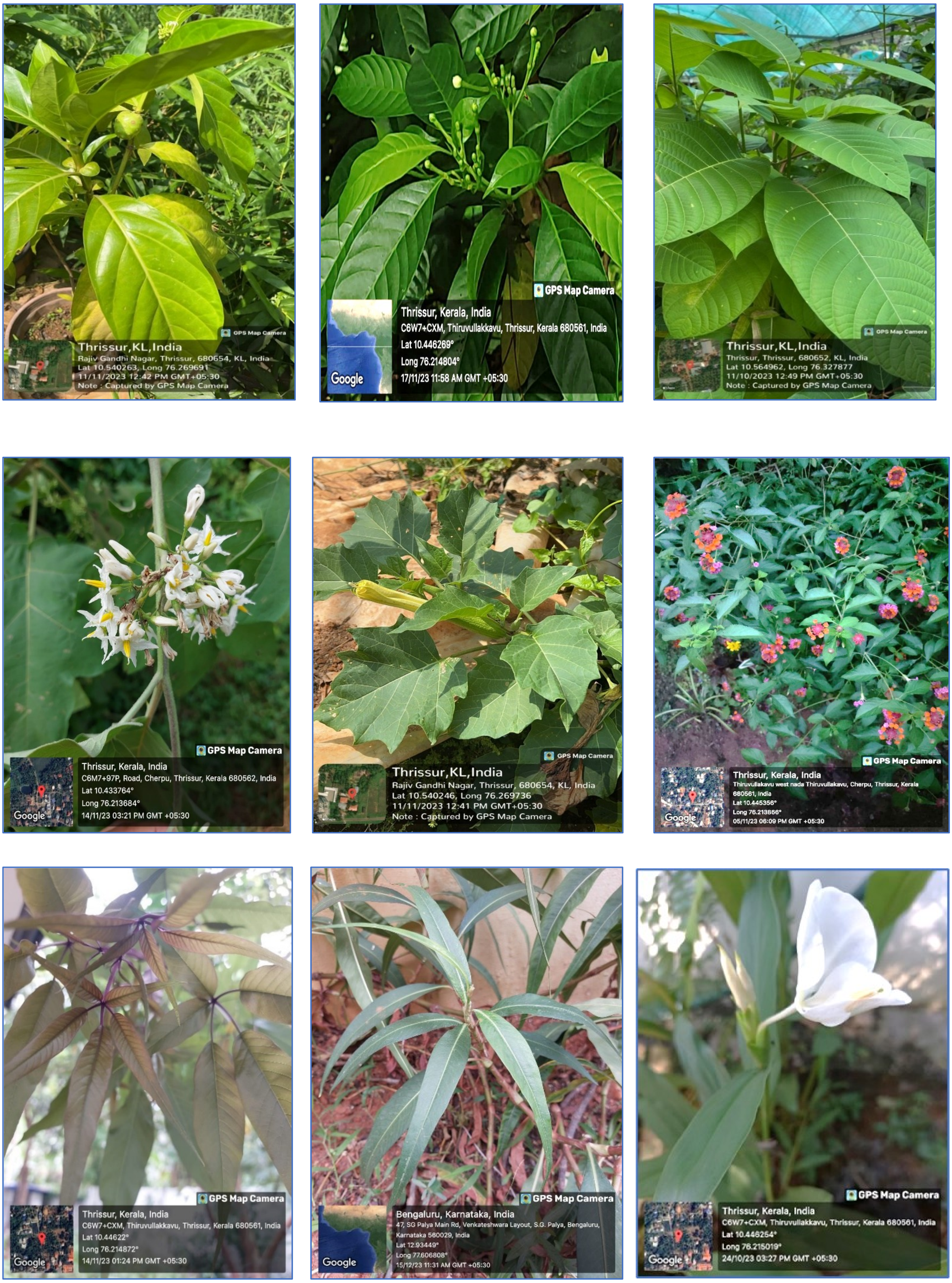

Fig. 5. Pictorial representation of plants used as larvicides.

(a) *Morinda citrifolia* ; (b) *Tarenna asiatica* ; (c) *Neolamarckia cadamba*; (d) *Solanum nigrum* ; (e) *Datura stramonium*; (f) *Lantana camara*; (g) *Vitex negundo* ; (h) *Aloysia citroda* ; (i) *Hedychium coronarium*

Fig. 6. Pictorial representation of plants used as larvicides.
(a) *Zingiber officinale* ; (b) *Curcuma longa*

Table 2. Plants and their lethal concentration of mosquito species

Sl. No	Name	Lethal concentration (LC 50)	Mosquito species	References
1.	*Delonix elata*	Leaf: 111.83ppm	*An. stephensi, A. aegypti, Cx. quinquefasciatus*	5, 6
2.	*Psorlea corylifolia*	Leaf: 699.915 ppm	*Cx. quinquefasciatus*	7, 8
3.	*Tamarindus indica*	Leaf: 0.3092	*A. aegypti, Cx. quinquefasciatus, A. lebbeck*	9
4.	*Leucas aspera*	Leaf: 35.624 ppm	*An. stephensi, Cx. quinquefasciatus, A. aegypti*	10, 11
5.	*Clerodendron viscosum*	Leaf: 172.7 mg/L	*Cx. quinquefasciatus, A. aegypti*	12, 13, 14
6	*Mentha piperita*	Leaf: 111.9 ppm	*A. aegypti, Cx. quinquefasciatus, An. stephensi*	15, 16
7	*Bauhinia variegate*	Leaf: 1.35mg/mL	*An. albopictus, An. stephensi, Cx. quinquefasciatus*	17, 18
8	*Cassia fistula*	Leaf: 45.57 ppm	*A. aegypti, Cx. tritaeniorhynchus, An. subpictus*	19, 20
9	*Cassia auriculata*	Leaf: 97.44 mg/L	*An. stephensi, An. subpictus grassi, Cx. tritaeniorhynchus*	21, 22
10	*Hibiscus sabdariffa*	Leaf: 528.44 ppm	*Cx. tritaeniorhynchus*	23, 24
11	*Sida acuta*	Leaf: 43 mg/L	*Cx. quinquefasciatus, A. aegypti, An. stephensi*	25, 26
12	*Corchorus capsularis*	Seeds: 1.020 ppm	*A. aegypti*	27
13	*Syzygium aromaticum*	Flower buds: 363.70µg/mL	*Cx. pipiens, A. aegypti*	28, 29, 30
14	*Eucalyptus teriticornis*	Leaf: 14.7 lg/mL	*A. aegypti, A. albopictus*	31, 32
15	*Callistemon rigidus*	Leaf: 39.15 ppm	*An. gambiae, A. aegypti, Cx. quinquefasciatus*	33
16	*Lantana camara*	Leaf (6 hrs): 119.71ppm	*Cx. pipiens, An. subpictus, A. aegypti, Cx. quinquefasciatus*	34, 35
17	*Vitex negundo*	Leaf: 2.4883mg/L	*Cx. tritaeniorhynchus, Cx. quinquefasciatus*	36, 37
18	*Aloysia citrodora*	Leaf: 65.6 µL/L	*Cx. quinquefasciatus*	38, 39
19	*Piper nigrum*	Fruit: 0.65 ppm	*Cx. pipiens pallens, A. aegypti*	40, 41
20	*Piper betel*	Leaf: 118.26 ppm	*A. aegypti, Cx. quinquefasciatus*	42, 43
21	*Piper longum*	Fruit: 0.248 ppm	*A. aegypti, Cx. quinquefasciatus, An. stephensi*	44, 45
22	*Morinda citrifolia*	Fruit: 358.11 ppm	*A. aegypti, Cx. quinquefasciatus, An. stephensi*	46, 47
23	*Tarenna asiatica*	Leaf: 1.288 µg/mL	*A. aegypti*	48, 49
24	*Neolamarckia cadamba*	Root: 253.7 µg/mL	*An. stephensi, A. aegypti, Cx. quinquefasciatus*	50, 51
25	*Solanum nigrum*	Leaf: 72.91 ppm	*Cx. quinquefasciatus*	52, 53
26	*Datura stramonium*	Leaf: 288 µg/mL	*An. gambiae, A. aegypti*	54, 55, 56
27	*Nicotiana tabacum*	Leaf: 0.50 mg/mL (100%)	*An. gambiae*	57, 58
28	*Hedychium coronarium*	Leaf (2hrs): 111ppm	*A. aegypti*	59, 60
29	*Zingiber officinale*	Rhizome: 197 ppm	*Cx. quinquefasciatus*	61, 62
30	*Curcuma longa*	Rhizome: 19.07 mg/L	*Cx. pipiens*	63, 64

Tamarindus: *Tamarindus* is a resilient evergreen that can reach a height of 20 meters. "Madras thorn" is a common moniker with spines and pendulous lateral branches. *T. indica* was examined against third-instar of *Aegypti* and *Cx. quinquefasciatus* mosquito larvae. Fresh leaves of the plant were collected, dried, crushed and extracted individually using petroleum ether in a Soxhlet apparatus. Using the WHO criteria, these samples were then evaluated for the presence of phytochemical ingredients and their larvicidal potential. The phytochemical analysis of the extract revealed the presence of alkaloids, glycosides, flavonoids, triterpenoids, saponins and tannins. The plant extracts demonstrated a noteworthy fatality of *Cx. quinquefasciatus* larvae around 97%, depending on the dose supplied, with an LC50 of 0.31 ppm for *A. lebbeck* (9).

Lamiaceae

Leucas aspera: *Leucas aspera,* a wild member of the Lamiaceae family, is well-known for its therapeutic qualities. In traditional medicine, the leaves of this plant are used to cure various conditions, including dyspepsia, fever, ulcers, coughing, colds and painful swellings. In rural regions, the leaves are utilized as an eco-friendly pesticide to target *An. stephensi* as well as a mosquito repellent against *Cx. quinquefasciatus* (10). In an experiment, the activity of the ethanol, aqueous methanol, petroleum ether and chloroform of plant extracts from *L. aspera* was tested against different mosquito species, such as *An. Stephensi, A. aegypti* and *Cx. quinquefasciatus*. After the treatment for 24 and 48 hours, the mortality rate of the fourth instar larvae of *A. aegypti, An. stephensi* and *Cx. quinquefasciatus* was examined and recorded independently at varying concentrations. The methanolic extracts exhibited an LC50 value against the *Cx. quinquefasciatus* approximately 37 ppm. The LC50 values for *A. aegypti* were 35.6 ppm in 24 hours and 64.3 ppm in 48 hours meanwhile, the ethanol extracts of *L. aspera* were reported to have LC50 values of around 40 ppm and 72.9 ppm against *An. stephensi,* respectively, after 24 and 48 hours. The extracts of this plant displayed formidable larvicidal efficacy. The replication of the former experiment confirmed that the plant acts as a (LC50: 35.6 ppm) potential larvicide (11).

Clerodendron serratum: *C. serratum* is a woody shrub that grows to a height of 3 to 8 feet and has blunt, quadrangular stems. It is native to east India and Malaysia. *C. Serratum h*as contributed significantly to the Indian medical system. Apart from the prevalent local application in respiratory ailments, other ethnomedical applications encompass managing pain, inflammation and malarial fever. It is also understood that they have anti-asthmatic and anti-allergic effects (12). In a research, hexane extract was found to have considerable growth-disrupting capability against *A. aegypti*. Four sets of phytochemical constituents-tannin, phytosteriod, cardiac glycoside and terpenoid were also detected. Plant extract with hexane was quite effective as a larvicide against *Cx. quinquefasciatus*. The hexane extract was effective as a larvicide to the fourth instar larvae of *A. aegypti* and *Cx. quinquefasciatus*, with EI50 values of around 8 mg/L and 19.5 mg/L respectively. When compared, the insect growth regulators used generally, such as methoprene had an ei50 value of around 0.05 mg/L. However, the hexane extract had a toxic effect on the non-target organism, namely, *Gambusia affinis*, although the lethal concentration (LC50=172.7 mg/L for 24 hours) for *Gambusia affinis* was considerably higher than the concentrations tested against *A. aegypti* and *Cx. quinquefasciatus*. The hexane extract effectively treated the fourth instar larvae of *A. aegypti* and *Cx. quinquefasciatus* and it showed EI50 values of around 8 mg/L and 19.5 mg/L respectively. In comparison, the insect growth regulator methoprene, which is being used standardly, had an EI50 value of approximately 0.05 mg/L (13, 14).

Pudina (Mentha piperita)

The common term for *Mentha piperita* is "pudina" which belongs to the Lamiaceae family. The fragrant herb *M. piperita* is well-known for its essential oils. Pharmaceutical-grade oil is produced by distilling recently collected aerial portions at the beginning of the blooming cycle. It contains several terpenoids in addition to menthol, esters, menthone, betaine, choline, carotenes, tocopherols, polymerized polyphenols and flavonoids. The major components of the herb's antibacterial effect include terpenoids found in the oil, including alpha or beta-pinene and ester-linked menthol. The volatile oil extracted from *M. piperita* showed a high rate of larvicidal activity when tested against dengue vector. An LC50 of 112 ppm was observed in the biological analysis following 24-hour exposure. When the oil was exposed to larvae for 48 hours, the oil toxicity rose by 11.8%. It was demonstrated that the exceptional repellent qualities of *M. piperita* essential oil work against adult *A. aegypti*. For 150 minutes, applying oil provided 100% protection. Only 1-2 bites were observed after 30 minutes, in contrast to 8-9 bites in the control arm (15). In a different study, third-instar mosquito larvae were exposed to *Mentha piperita* (peppermint oil) to test its larvicidal properties against *A. aegypti, An. stephensi* and *Cx. quinquefasciatus*.

In comparison, *Cx. quinquefasciatus* was the most sensitive of the three species studied, followed by the aforesaid species. 100% mortality for *A. aegypti* was reached at 3 ml/m^2 in 48 hours or 4 ml/m^2 in 24 hours; meanwhile, at 4 mL/m^2 in 72 hours, 100% mortality for *An. stephensi* was noted. Additionally, there was a significant inhibition in the emergence at 3 ml/m^2 and those who emerged did not oviposit even after a blood meal. When applied to human skin, the oil acted as a strong insect repellent (16).

Kanchan (Bauhinia variegata): Known by "kachnar," *Bauhinia variegata* Linn. (Leguminosae) is a medium-sized tree extensively seen in tropical countries and prevalent in South India. The chemical components that have been extracted from the plant thus far are apigenin, apigenin-7-o-glucoside, heptatriacontan-12, 13-diol, B-sitosterol, kaempferol-3-glucoside, tannins, carbohydrates, amides, reducing sugars, crude protein, fibers, calcium and phosphorus (17).

Plant derivatives can be developed into inexpensive, ecologically acceptable biopesticides because they are enhanced with active compounds with excellent mosquitocidal effects. At concentrations of 100, 120, 140, 160, 180 and 200 mg/100 mL of tap water, the macerated leaf powders of *B. variegata* were evaluated against various mosquito species for up to a 24-hour exposure period. Using *B. variegata* leaf powder, the LC50 values for *A. albopictus, An. stephensi* and *Cx. quinquefasciatus* were 133.3, 125 and 135.3 mg/100 mL, respectively. According to this study, *B. variegata* exhibited 100% mortality against several mosquito species, including *Cx. sparsiflorus* (18).

Cassia fistula: *Cassia fistula l*. Is an Indian labernum which is commonly known as the "golden shower" with yellow inflorescence and long black pods containing seeds. Along with its pharmacological uses, the extract is often used for pest and disease control. There has been a strong quest for plants with unique insecticidal components (19). In one study, the larvicidal and repellant properties of *C. fistula* leaf extract were investigated against *A. aegypti* using three different solvents: methanol, benzene and acetone. The methanol extract showed the highest level of effectiveness out of the three solvent extracts. *C. fistula* exhibited LC50 values of 45.6 and 33.8 ppm, respectively, against the early third instars of *Cx. tritaeniorhynchus* and *An. subpictus* (20).

Cassia auriculata: This plant is a common variety seen in wild with bright yellow-coloured flowers and compound leaves. The thorns present in the stem make it hard to be destroyed. The leaf extract was isolated using different chemicals such as acetone, dichloromethane, diethyl ether, hexane and methanol, in which hexane exhibited the highest LC50 value, i.e., 97.44 mg/L; with *An. stephensi*. When comparing egg and pupal mortality, leaf extract with methanol shows 91.4% and 98% mortality at 250 mg/L concentration with 2% adult emergence. Since the control sample observed no mortality, it can be concluded that the leaf extract caused the mortality (21). The mortality of third-staged larvae of *An. subpictus Grassi* and *Cx. tritaeniorhynchus* with leaves and flower extracts using petroleum ether and methanol was conducted, which shows the following result in table 3 (Table 3, 4, 5) (22).

Malvaceae

Hibiscus sabdariffa: The genus *Hibiscus* (Malvaceae) consists of more than 300 species of annual or perennial herbs, shrubs and trees. *Hibiscus sabdariffa* L. (hs), commonly referred to as roselle, is a crop that is well suited for developing nations due to its ease of cultivation, ability to be cultivated in multi-cropping systems and potential uses as both food and fiber (23, 24).

The role of *hibiscus sabdariffa* calyces methanol extract in preventing the proliferation and dissemination of *Cx. tritaeniorhynochus* was examined in a study. *Cx. tritaeniorhynochus* larvae in their third instar were fed and left in the light for eighteen hours. According to the results, the test sample had over 80% mortality, with an LC50 of 528.44 ppm (23).

Sida acuta: Is an erect, branched, perennial small shrub that grows in waste and open lands. The stem is smooth and greenish, the flowers are small, yellow solitary, the leaves are compound and lanceolate and the seeds are smooth and black. The LC50 value ranges between 38 to 48 mg/L. The ethanolic extraction of these leaves provides anti-plasmodial properties against two strains of *Plasmodium falciparum* (25, 26) (Table 6).

Corchorus capsularis: This herb can grow up to 3.5 meters tall, with a straight, smooth, cylindrical stem and branching top section. White jute (*Corchours capsularis*) is thought to have originated in South China and Indo-Burma. The seeds contained olitoriside, erysimoside, strophantidol glycosides, oliogosaccaride, corchorin, corchortoxin helveticoside, corchorosides a and b, biosides and olitoriside. Apart from raffinose and various kinds of oil (namely palmitic acid, stearic

Table 3. Effect (LC50) of *Cassia auriculata* leaf extract on *An. stephensi*: concentration and egg mortality

Sl. No	Extracted with	Lethal concentration (LC 50) (mg/L)	Concentration	Egg mortality (%)	References
1			0.05 g/L	21.2	21
2			0.1 g/L	38.4	21
3	Hexane	78.44	0.15 g/L	45.8	21
4			0.2 g/L	64.4	21
5			0.25 g/L	75.2	21
6			0.05 g/L	27.6	21
7			0.1 g/L	41.8	21
8	Diethylether	86.33	0.15 g/L	55.6	21
9			0.2 g/L	69.8	21
10			0.25 g/L	80.4	21
11			0.05 g/L	36.4	21
12		89.47	0.1 g/L	45.6	21
13	Dichloromethane		0.15 g/L	68.4	21
14			0.2 g/L	72.6	21
15			0.25 g/L	84.6	21
16			0.05 g/L	38.8	21
17		97.44	0.1 g/L	52.8	21
18	Acetone		0.15 g/L	72.8	21
19			0.2 g/L	81.4	21
20			0.25 g/L	86.6	21
21			0.05 g/L	42.4	21
22			0.1 g/L	59.6	21
23	Methanol	74.82	0.15 g/L	73.6	21
24			0.2 g/L	86.8	21
25			0.25 g/L	91.4	21

Table 4. Pupal mortality and adult emergence of *An. stephensi* treated with *Cassia auriculata* leaf extract and associated extraction chemicals

Sl. No	Extracted with	Concentration	Pupal mortality	Adult emergence (%)	References
1.	Acetone	0.125 g/L	88.0	12.0	21
2.		0.25 g/L	97.4	2.6	21
3.	Dichloromethane	0.125 g/L	75.6	24.4	21
4.		0.25 g/L	85.4	14.6	21
5.	Diethyl ether	0.125 g/L	82.6	17.4	21
6.		0.25 g/L	94.0	6.0	21
7.	Hexane	0.125 g/L	74.6	25.4	21
8.		0.25 g/L	89.4	10.6	21
9.	Methanol	0.125 g/L	91.4	8.6	21
10.		0.25 g/L	98.0	2.0	21

Table 5. Lethal concentration (LC50) of *Cassia auriculata* leaf and flower extracts against *An. subpictus grassi* and *Cx. tritaeniorhynochus*

Sl. No	Plant part	Extracted with	Species	Lethal concentration (LC 50) (ppm)	References
1	Leaf	Petroleum ether	*An. subpictus grassi*	44.21	22
2	Flower	Methanol		44.69	22
3	Leaf	Petroleum ether	*Cx. tritaeniorhynchus*	69.83	22
4	Flower	Methanol		51.29	22

Table 6. Leaf extracts of *Sida acuta* and its LC50 effect on *A. aegypti, An. stephensi* and *Cx. quinquefasciatus*

Sl. no	Species	Lethal concentration (LC 50)	100% protection by 5.0 mg/L (minutes)	Lethal concentration (LC 50) by silver nanoparticles (µg/mL)	References
1	*A. aegypti*	42.08 mg/L or 119.32 µg/mL	150	23.96	26
2	*An. stephensi*	38.64 mg/L or 109.94 µg/mL	180	21.92	26
3	*Cx. quinquefasciatus*	47.91 mg/L or 130.30 µg/mL	120		26

acid, linoleic acid, linolenic acids, lignoceric acid and oleic acid), significant levels of B, Mn, Mo and Zn were also found in the seed. Furthermore, catechine, flavonoids, triterpenes, β-sitosterol, saponins, glucoside, fusidic acid, scopoletin capsularin and caffeine were isolated from *Corchorus capsularis* leaves. A new triterpene glycoside known as capssin and capsugenin 30-o-glucopyranoside was isolated from their leaves. The plant was used in an experiment to combat *A. aegypti* larvae in their late third instar. They were subjected to varying amounts of aqueous extract from fresh plant seeds (5%, 4%, 3%, 2% and 1%). Maximum mortality (95%) was noted in crude seed extract of *Corchorus capsularis* after a 24-hour exposure. The fresh seed extract had a minimum LC50 value of 1.020 ppm (27).

Myrtaceae

Syzygium aromaticum: An indonesian native, *Syzygium aromaticum* (l.) is a member of the Myrtaceae family of trees. Cloves are the plant's fragrant flower buds frequently used as a spice. The main reason cloves are gathered is for their unopened flower buds, which are borne in clusters and dried to form complete clove buds-the well-known spice used in trade. Ground clove, oleoresins and volatile oils made from clove bud stems or leaves are other goods made from cloves. The volatile oils found in cloves include pinene, methyl salicylate, β-caryophyllene, acetyl eugenol and up to 95% eugenol (28).

According to certain research, cloves and clove oil have antibacterial, anti-fungal and antiseptic properties. As a result, their use is predicted to rise in tandem with the "back to nature" movement, which promotes a preference for natural products. With corresponding LC50 value of 363.70 µg/mL against *Cx. Pipiens*, the hexane extract of *Syzygium aromaticum* demonstrated efficacy against the larvae (29).

Eugenol was determined to be the primary constituent of *S. aromaticum*, making up 65.99% of the essential oil in a different study. Evaluations were conducted on the effect of essential oils on vector oviposition and the 50% lethal concentration (LC50) of the essential oil using temephos. The results of the *Ae. Aegypti* larvae susceptibility experiments showed that the essential oil of *S. Aromaticum* has larvicidal effects on all examined populations (30).

Eucalyptus teriticornis: *Eucalyptus* is one of the most significant trees and is extensively planted worldwide. It is a member of the Mytraceae family with more than 600 species. In Chinese traditional medicine, numerous members of the *Eucalyptus* genus, which belongs to the Myrtaceae family, are used to treat various ailments. The leaves of the Eucalyptus genus contain aromatic oils that have a distinct smell. These oils can be recovered by steam distillation, which yields essential oils. The relative concentrations of the two primary components of eucalyptus essential oils-p-cymene and 1,8-cineole-can be used to determine their larvacidal activity. The high concentration of 1,8-cineole in these oils accounts for a significant portion of their adulticidal efficacy. The findings indicate that essential oils have a lower larvicidal effectiveness and a more adulticidal effect (31).

According to a study, out of the twelve compounds that were examined over 24 hours, 1,8-cineole, α-terpinyl acetate, α -terpineol, terpinen-4-ol, etc., demonstrated an LC50 greater than 50 lg/mL against *A. aegypti* and *A. albopictus* larvae. As a result, these compounds were deemed inert. Conversely, *A. aegypti* and *A. albopictus* larvae were significantly inhibited by α-phellandrene, limonene, p-cymene, c-terpinene, terpinolene and α-terpinene (LC50 < 50.0 lg/mL).

Out of all, α-terpinene showed the highest *A. aegypti* larvicidal activity in 24 hours with an LC50 value of 14.7 lg/mL. α-phellandrene, limonene, p-cymene, terpinolene and c-terpinene followed suit, with LC50 values of 16.6 lg/mL, 19.2 lg/mL and 30.7 lg/mL, respectively. In a different study, 100 mg/L of 1,8-cineole caused 100% larval death in *A. aegypti* after one day (32).

Callistemon rigidus: *Callistemon rigidus*, or stiff bottlebrush, is a bushy tree belonging to the Myrtaceae family. It grows mainly in Australia but nowadays can be found throughout the world. It has pink-red blooms and narrow, pointed, black leaves. The main phytocomponents of *C. rigidus*'s essential oil are cineol, flavone, flavonol and triterpenoid; tannins and flavonoids are present in the plant's leaves. Essential oils from *C. rigidus* are harmful to the mosquito species *An. gambiae*, *A. aegypti* and Cx. quinquefasciatus. The plant's leaf fractions and extracts shown efficacy against *Callosobruchus maculatus*, a bean beetle pest. A different study assessed the larvicidal effectiveness of *C. rigidus* methanol extracts and essential oils using the WHO-standard technique against *A. gambiae* larvae. It was shown that the methanol extract of *C. rigidus* had a very high mortality % of *A. gambiae* larvae treated with it, with an LC50 (ppm) value 24 hours after exposure (33).

Piperaceae

Piper nigrum: It is a widely used spice of high economic importance called pepper. Their dried fruits have high medicinal properties and have been used since the olden days in South India. This is a climbing shrub that has inflorescence and small flowers. The fruit comprises alkaloids, flavanones, propenylphenols, terpenes, neolignans, pyrones, steroids, piperolides, flavones, chalcones and lignans. Major constituents are pipzubedine, pipilyasine, pellitorine, pipyaqubine, piperine and pipericine (34). Other compounds such as dodecanol, myristicin, 1,3-benzodioxole, sesamin, sesaimol and piperonal showed larvicidal properties. In this case, dodecanol showed the strongest properties by reducing surface tension. Myristicin from *Piper nigrum* exhibited an LC50 value of 15.3 g/ mL against *A.* species, while LC50 was 0.56 lg/ mL against *Culex* species. This shows that larvicidal property varies in different mosquito species (35).

Piper betle: This common climber has inflorescence with small flowers and heart-shaped leaves. It comprises chavibetol, chavicol, cadinene and hydroxychavicol (36) and bioactive compounds like 4,7- methanoazulene, benzene, 1-cyclopropanaphthalene, 2h- 2,4amethanonaphthalene, alpha-caryophyllene, alpha-cubebene, 1h-cycloprop(e) azulene, 1,6-cyclodecadiene, cyclohexane, diethyl phthalate, caryophyllene, tridecanoic acid, octadecane, benzoic acid, phenol and hexadecanoic acid, 4-allyl-1,2-diacetoxybenze and 3-(3-fluoroanilino)- 1-(3-nitrophenyl)-1-propanone and benzene. Caryophyllene provides larvicidal property. The secondary metabolites include carbohydrates, flavonoids, alkaloids, steroids, terpenoids, proteins, tannins, glycosides, phenolic compounds and saponins, whose examples are listed above. The LC50 value was 118.26 ppm and ethanolic extract showed 100% mortality (37). Even 1.5 mg/L showed mortality above 90%; thus, we can conclude that *Piper betle* is an excellent mosquito control with larvicidal properties (36).

Piper longum: This is also a variety of pepper known for its medicinal properties and a commonly used spice. They have long dark-coloured fruit and long inflorescences with small flowers. The plant comprises, alkaloids, flavonoids, tannins, saponins, phlobatannins and amino acids; they are 9,12-octadecadienoyl chloride, phytol, tetradecanoic acid, 4-chromanol, 2,4-ditertbutylphenol, n-hexadecanoic acid phenol, 4- (2-propenyl), oleic acid, cis-vaccenic acid, eugenol, butanoic acid. (Table 7).

For *A. aegypti,* a high LC50 value was shown with methanol*; An. stephensi* and *Cx. quinquefasciatus,* the highest value exhibited by petroleum ether and methanol, respectively. *Piper longum* extracts have 100% mortality and ovicidal activity (38). After three minutes of exposure, the symptoms constitute abnormal motion patterns like excitation, convulsions, paralysis, restlessness, or sluggishness. The ethanolic extracts created toxic effects in neuro-muscular systems and half the larvae were killed within 2 hrs of exposure. The LC50 value of *Piper longum* is 0.248 ppm (39).

Rubiaceae

Morinda citrifolia: *Morinda citrifolia* is a tree with compound leaves and white inflorescence. It is widely used for fruit and has medicinal properties. Seventeen major compounds are present, including octoanoic acid, scopoletin, vitamin c, potassium nordamnacanthal, rubiadin, morindone, b-sitosterol, rubiadin1-methyl ether, vitamin a, carotene, caproic acid, linoleic acid, acubin, l-asperuloside, alizarinursolic acid, caprylic acid, proxeronine, rutin, cytidine, borreriagenin, deacetylasperuloside, d-glucose, epi-dihydrocornin, dehydromethoxygaertneroside, methyl beta-d-fructofuranoside, methyl alpha-d-fructofuranoside, 6 α-hydroxyadoxoside and 6 beta, americanin a, 7 beta-epoxy-8-epi-splendoside, narcissoside, asperuloside, citrifolinin b epimer a, asperulosidic acid, citrifolinin b epimer b, methyl alpha-d-fructofuranoside, d-mannitol, d-glucose, d-glucose and β-sitosterol 3-o-betad-glucopyranoside. This can be classified as saponins, amino acids, tannins, anthraquinones, triterpenes, flavone glycosides, alkaloids, flavonoids and terpenoids (40). (Table 8, 9). The highest LC50 value was 358.11 ppm for *Cx. quinquefasciatus,* fifth instar larva. The fifth instar larvae showed a high LC50 value. In *An. stephensi* fifth instar larvae at 24 hours exhibited a high LC50 value (41).

Tarenna asiatica*:* It is a shrub in the wild with white-colored inflorescence and a simple leaf with reticulate venation. The phytochemistry has saponins, flavonoids and alkaloids, while functional groups include aromatic compounds, ethers, alkyl halides and alcohols. Three compounds are 2-methyltetracosane, eicosane and tetracontane. Even the silver nanoparticles extracted from them show larvicidal properties (42). The normal plant extract shows significant pupicidal, larvicidal and adulticidal properties. The LC50 values are 1.288 ppm and 1.284 ppm with acetone and methanol, respectively. The LC50 values for pupicidal adulticidal effect are 3.273 ppm and 12.142 ppm with acetone and hexane (43).

Neolamarckia cadamba: Wild cinchona is a tree with compound leaves and brightly coloured inflorescence is widely found in South Asia, especially in Nepal, India, Sri Lanka, Myanmar, Bangladesh, Philippines, Papua New Guinea and Indonesia (44). The phytochemical includes triterpenoid glycosides, triterpenes,

Table 7. Effect of *Piper longum* leaf extracts on *A. aegypti, An. stephensi* and *Cx. quinquefasciatus*

Sl. No	Extracted with	Mosquito species	Lethal concentration (LC 50) (ppm)	References
1		*A. aegypti*	50.81	38
2	Aqueous	*An. stephensi*	133.42	38
3		*Cx. quinquefasciatus*	257.70	38
4		*A. aegypti*	213.88	38
5	Petroleum ether	*An. stephensi*	223.70	38
6		*Cx. quinquefasciatus*	289.92	38
7		*A. aegypti*	389.33	38
8	Chloroform	*An. stephensi*	219.34	38
9		*Cx. quinquefasciatus*	234.45	38
10		*A. aegypti*	395.51	38
11	Methanol	*An. stephensi*	134.712	38
12		*Cx. quinquefasciatus*	315.35	38

Table 8. Mosquito species with their instar stages and LC50 of *Morinda citrifolia* leaf extracts

Sl. No	Mosquito species	Instar stages	Lethal concentration (LC 50) (ppm)	References
1.1		1st	181.27	40
1.2		2nd	210.40	40
1.3	*A. aegypti*	3rd	229.80	40
1.4		4th	256.73	40
1.5		5th	292.01	40
2.1		1st	146.08	40
2.2		2nd	159.07	40
2.3	*An. stephensi*	3rd	172.16	40
2.4		4th	185.08	40
2.5		5th	202.68	40
3.1		1st	226.70	40
3.2		2nd	256.97	40
3.3	*Cx. quinquefasciatus*	3rd	290.05	40
3.4		4th	316.33	40
3.5		5th	358.11	40

Table 9. Instar stages of *An. stephensi,* with their exposure time and LC50 of *Morinda citrifolia* leaf extracts

Sl. No	Instar stages of ***An. stephensi***	Exposure time	Lethal concentration (LC 50) (mg/L)	References
1.1	First instar	24	152.05	41
1.2	Second instar	24	190.22	41
1.3	Third instar	24	237.43	41
1.4	Fourth instar	24	273.12	41
1.5	Fifth instar	24	305.25	41
2.1	First instar	48	202.47	41
2.2	Second instar	48	95.75	41
2.3	Third instar	48	57.52	41
2.4	Fourth instar	48	18.30	41
2.5	Fifth instar	48	97.78	41

flavonoids, saponins, 3a-dihydro-cadambine, indole alkaloids, isocadamine, isodihydrocadambine and cadamine. Even though the leaves, bark and roots show larvicidal properties, the roots exhibit the largest larvicidal effects (45). The larvicidal effect for 1st, 2nd, 3rd and 4th instar stages was 12.15 ppm, 15.15 ppm, 21.82 ppm and 31.29 ppm, respectively (44) (Table 10).

Solanaceae

Solanum nigrum*:* This plant is a small and delicate herb whose leaves are used as vegetables; they have simple, hairy, elliptical leaves with white inflorescence and black fruits; hence the name black night shade. They constitute glucosinolate compound which is 1-thio-β-d-glucopyranose-1-[(r)-3-hydroxy-2-ethyl-n hydroxysulfonyloxy propanimidate] (46). 0.5%, when used with ethyl acetate provide high larvicidal properties (47) (Table 11).

Datura stramonium*:* This medicinal herb is found in the wild with simple, long leaves and white, solitary, trumphet shaped flowers. They have alkaloids and flavonoids, which release poisons. The LC50 is .82 ppm. 5mg/mL can provide complete protection for 120 minutes (48). The petroleum ether extract is more powerful and, in 24 hours, showed 100% mortality. The behavioral changes observed were restlessness and loss of equilibrium (49).

Nicotiana tabacum*: Nicotiana tabacum* is an herb with simple leaves and brightly coloured inflorescence. It was widely cultivated and also used as a pesticide (50). It consists of pyridine (alkaloids) and nicotine. The 100% mortality was shown at 0.5 mg/ml (51). At 0.1%, six larvae died while in 0.2% and 0.4%, 12 and 24 died, which is the double number proving the larvicidal efficiency. The agglutinin compound has toxic effects on insect groups, specifically Lepidoptera (50) (Table 12).

Verbenaceae

Lantana camara: *Lantana camara* is an invasive shrub with colorful inflorescence that can be spotted in the wild and treated as an ornamental plant. This is one of the toxic plants used as mosquito repellent, but studies show no toxic effects when treated in rats (52). The components of the leaf include β-caryophyllene, caryophyllene oxide, germacrene d, α-

Table 10. Chemicals used for extraction of leaf and root extracts from *Neolamarckia cadamba* along their LC50 and mosquito species

Sl. No	Mosquito species	Plant part	Extracted with	Lethal concentration (LC 50) (ppm)	References
1	*A. aegypti*	Leaf	Petroleum ether	82.66	45
2		Root	Methanol	253.73	45
3	*An. stephensi*	Leaf	Petroleum ether	61.36	45
4		Root	Methanol	43.29	45
5	*Cx. quinquefasciatus*	Leaf	Petroleum ether	124.75	45
6		Root	Methanol	99.51	45

Table 11. Chemicals used for extraction of *Solanum nigrum* leaves and their (LC50) effect on *Cx. quinquefasciatus*

Sl. No	Extracted with	Lethal concentration (LC 50) (ppm)	References
1	Acetone	72.91	46
2	Absolute alcohol	59.81	46
3	Petroleum ether	54.11	46
4	Chloroform: methanol	32.69	46
5	Benzene	27.95	46
6	Ethyl acetate	17.04	46

Table 12. LC50 with their exposure time and the mortality rate of *An. gambiae* with the *Nicotiana tabacum* leaves

Sl. No	Exposure time	Concentration (ppm)	Mortality (%)	References
1	24 hours	300	78.7	51
2		400	89.3	51
3		500	100	51
4		300	85.3	51
5	48 hours	400	69.3	51
6		500	78.7	51

curcumene, bicyclosesquiphellandrene, delta-cadinene, β-pinene, limonene, β-elemene, α- caryophyllene, α-cadinol and β-cubebene, α- humelene and eucalyptol (53). The highest LC50 value was 119.71 at 6-hour exposure. Meanwhile, LC50 values at 12 hours are 70.7 and 24 hours at 45.3. 80% and above larvicidal activity was observed with these mosquito species, *An. subpictus, A. aegypti, Cx. quinquefasciatus.* 100 ppm concentration gives the best result (52).

Vitex negundo: It is a highly branched shrub with a heavily scented purple-colored inflorescence. Their leaves are pointed and compounded, as seen in a branched fashion (54). *Vitex negundo* is one of the thirteen species found in India (55). The major constituents are terpenoids, flavonoids, lignans and fatty acids. Terpenoids constitute germacrene d, 1,8-cineole, α-pinene, linalool, α-guaiene, caryophyllene oxide, while palmitic acid and linolenic acid are in fatty-acids (56). LC50 value is 2.4883mg/L and the leaf extract is highly effective in protecting from *Anopheles, Culex* and *Aedes* species. 2mg/cm^2 can protect for 8 hours with zero side effects (54). Compared to other species of *Vitex*, *V. negundo* exhibits the least larvicidal property (55).

Aloysia citrodora: This shrub, with pointed leaves and inflorescence, is used for medicinal and ornamental purposes. This is commonly found in South America and is used as a mild sedative. Ninety-two components are found in the leaf. The major constituents are citral (geranial and neral-isomeric forms), d- limonene, neral, bicyclogermacrene, isospathulenol, caryophyllene oxide and p-cymene (57). Other compounds include 1,8-cineole, ar-curcumene, spathulenol. Geraniol and neral give the adulticidal, whereas spathulenol and caryophyllene oxide give the larvicidal property against *Cx. quinquefasciatus*. These compounds can be classified into monoterpene hydrocarbons, oxygenated monoterpenes and sesquiterpenes (58).

Zingiberaceae

Hedychium coronarium: It is widespread land in different parts of Asia and is used as an odorant. They have white flowers, which is seen as an inflorescence. From their rhizome, which is a means of propagation, 44 constituents were identified (fresh) and from dried 38 constituents. Fresh rhizomes showed more activity compared to dried rhizome. From leaves, 30 components were distinguished.The larvicidal activity was checked from rhizome and leaf; both have alpha-pinene, 1,8-cineole, beta-pinene, characteristic properties for the family Zingiberaceae. The composition of leaves includes α- pinene, β -pinene, 1,8-cineole, r-elemene and carotol (59); meanwhile, rhizome contains β-pinene, α-terpineol, α- pinene and 1,8-cineole; dried one varies from the fresh one by having cymene & terpinen4-ol (60). The LC50 values were 90ppm and 47ppm for 24 hours while 111ppm and 86 ppm for 2 hours, respectively and the mosquito larvicidal property is exhibited by the presence of β-pinene, 1,8-cineole and α- pinene (59).

Zingiber officinale: This is a very common tuberous plant found in South Asia and it is widely used for cooking due to its numerous qualities. They have brightly colored inflorescences and pointed leaves. They have a non-volatile compound named oleoresin and phenols like zingiberol and β-eudesmol in their rhizomes, which express mosquito larvicidal activity (61). The compound from the rhizome showed more toxicity to all four instar stages and 100% mortality of pupae. They even showed oviposition deterrence and more toxicity towards *A. aegypti* (62). Forty-eight hours of exposure to 100 ppm oil showed the highest toxicity, 100% mortality, inhibition of pupae development and provided 5 hours of protection. The lethal concentration LC50 for *A. aegypti* & *Cx. quinquefasciatus* were 154 ppm and 197 ppm, respectively (61).

Curcuma longa*:* This is a traditional plant with high antimicrobial properties used in culinary science. They also have high mosquito larvicidal property, especially to *A. aegypti, A. albopictus, A. quadrimaculatus* and *Cx. pipiens* (63). The major constituents are curcumene, xanthorrhizol, phellandrene 1,8-cineole, p-cymene, tumerone, 7-zingiberene, turmerone, bis-demethoxycurcumin, 9-oxoneoprocurcumenol, 1h-3a, 7-methanoazulene 1,8-cineole, neoprocurcumenol and bis-demethoxycurcumin. Demethoxycurcumin and demethoxycurcumin are known as curcuminoids (64). 50% of turmeric has turmerone, classified into ar-turmerone and 8-hydroxyl-arturmerone; which showed lethal concentrations of 138.9 ppm and 257.7 ppm after 24 hours of exposure, respectively (63). Curcumin showed high larvicidal activity, which was 19.1 ppm (64).

Conclusion

From the above data, it is clear that at least one or two plants in almost all the plant families are synthesizing phytochemicals with mosquito larvicidal properties. In the places where a high number of mosquitoes are observed, these plants can be planted, which controls the situation to an extent. Many of these plants are naturally grown; thus, little care is required and they are acquired in higher amounts. Even common people can be a part of this and adapt to planting the above plants since it is cost-effective. In highly populated areas, the plant extracts can be sprayed which serve as an environmentally friendly approach. All mosquitoes can't be eradicated since this disturbs the food chain, so the interactions can be minimized and the number shouldn't exceed the control limit. Future generations won't be affected by using these natural controllers and they will be safe. The chemicals in the synthetic larvicides and insecticides enter the food chain, leading to bioaccumulation and causing destructive effects. If this scenario continues, the future will be in great disaster with serious health problems. This review comprises traditional and common plants from 10 different families where 3 plants are targeted as an example case. These are normally prevalent as medicinal plants in various regions of the world.

Acknowledgements

The authors would like to express their sincere gratitude for the consistent support and guidance they have received from the Department of Life Sciences, at CHRIST University.

Authors' contributions

PM initiated the study and primary outline and KS completed the manuscript.

Compliance with ethical standards

Conflict of interest: The authors hereby declare that they have no conflict of interest and have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical issues: None

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