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Review Article

Indigenous Plants and their Larvicidal Potential against Indian Mosquito Vectors: A Review

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ABSTRACT

All over the world, millions of people are suffering from mosquito borne diseases spreading by bacteria, viruses or parasites and transmitted by mosquitoes to humans. It is estimated that about billions of currencies are spent by nations annually due to these diseases and millions of people dye as a consequence of catching mosquito borne diseases. The World Health Organization has recorded mosquitoes borne diseases as one of the topmost threats to public health, particularly in developing countries. In India, it has been estimated that annually more than 40 million people suffer from mosquito illness. Mosquito control includes target killing the larvae of mosquitoes even before they emerge into adults via using botanical extracts as an alternative larvicides. Herbal plants having a good medicinal values and potential so now a days it has been used as an insecticide at an individual and community level. These are non-toxic and biodegradable measures that are easily available and inexpensive depicting broad spectrum potential against the various strains of mosquitoes. Existing studies have taken in account the probit analysis for the calculation of percentage, $LC_{50,}$ LC_{90} values and 95% confidence limits to propound the observed relationship between the mortality percentage of larvae and logarithmic concentration of the active constituents found in herbal extracts. In this article, we reviewed on the current state of knowledge available on the larvicidal value of plant extracts and mosquitocidal activity, the nature of active parts of plant and promising advances, knowledge to make herbal or biological control of various species of mosquitoes as a potential eco-friendly and safe larvicides.

Keywords: Mosquito Borne Disease, Larvicide, Herbal Plants, Insecticide

Introduction

The different species of Mosquito play their role as a vector for most of the life suffering diseases namely dengue fever, malaria, chikungunya fever, yellow fever, filariasis, encephalitis and West Nile virus infection, throughout the world. Approximately out of 4000 different species, less than 10% of mosquito species are suitable vectors of pathogenic agents of mosquito illness diseases. According to Taubes (1997) diseases transmitted due to mosquitoes are said to be a prominent cause of mislaying of human life worldwide. Diseases transmitted by mosquito species show an economic impact such as: loss in social and commercial outputs, especially in subtropical and tropical countries (Fradin and Day, 2002).

Annually, more than 40 million people are suffering from mosquito transmitted diseases. Dengue is the most dangerous and deadliest diseases among the people living in subtropical and tropical climate. The symptoms of dengue fever ranges from mild to severe and lead to life threatening disease. According to WHO (2015) estimation, 128 countries possess the risk of dengue infection globally with total estimate of 390 million dengue cases per year. In the year 2014 to 2015 dengue cases raised upto in doubling ratio in India in which 1800 cases were reported in Delhi itself. Chikungunya, yellow fever, dengue fever, hemorrhagic fever and zika virus infection is transmitted by the *Aedes* mosquito worldwide.

Aedes is a genus of mosquitoes, originally found in tropical zones of Southeast Asia which includes India, but these are now found in all the continents except Antarctica. Human activity plays an important role in spreading some of *Aedes* species. According to WHO (2016), the diseases transmitted by *Aedes* mosquito create a special focus in the field of public health and millions people are affecting every year. *Aedes aegypti* is supreme species of mosquito for the transmission of dengue fever due to wide distribution and its association with people. Infectious blood ingesting by the arbovirus vectors, female *Ae. aegypti.* In the past few decades, this species has undergone a dramatic global expansion to many countries through the transport of goods including used-tire trade and international travel.

Apart from dengue, malaria also emerged as a prevailing problem, especially in the developing countries like India. According to WHO estimate there are approximately 400 million clinical cases and 1.5 to 2.7 million deaths due to malaria worldwide. In the last 50 years many complications were observed to prevent the infections occurred due to increase in the drug resistivity (Manguin, 2008). Epidemiology and other factors responsible for malaria transmission vary from place to place. In India almost 1000 deaths are occurring every year because of vector borne diseases. During 2002 out of the total 18, 23,320 positive cases, 50.93 % were due to *Plasmodium vivax* and 49.07 % were due to *Plasmodium falciparum*. There are 58 *Anopheles* species distributed unevenly all over the country. However, not all *Anophelese* are epidemiologically important and play important role in transmission. The major vector species are: *An. culicifacies, An. stephensi, An. fluviatilis, An. minimus, An. dirus* and *An. sundaicus*. *An. culicifacies* is found to be responsible for about 60-70% of causing malaria in India.

According to WHO (2008), another most common arthropod infectious disease is lymphatic filariasis. 128 million people affected by this disease in 78 endemic countries. Generally these infectious diseases are found in tropical areas of Asia, Africa, the western Pacific and America. Annually 1.3 billion people are found at risk for lymphatic filariasis infection in which 454 million are only Indians.

In India, filariasis is endemic in twenty states covering 250 districts and 553 million people at a risk of infection (Thomas *et al.*, 2013). First time Lewis (1872) in Calcutta investigated the microfilariae in the peripheral blood. Majority states of North-West (Himachal Pradesh, Haryana, Delhi, Punjab, Rajasthan and Uttaranchal) and some states of North-East (Arunachal Pradesh, Sikkim, Nagaland, Manipur, Mizoram and Tripura) are free from the filarial infection. According to Manguin (2008) *Culex* and *Anopheles* vector species of mosquito are transmitted the infection from *Wuchereria bancrofti* although it is not so fatal. Bernhard (2003) reported that *Culex quinquefasciatus* is the main responsible vector of filariasis and mainly found in areas of subtropical America (Weinstein *et al.,* 1997), Afrotropics (White, 1975), Australasian (Lee *et al.,* 1989), Indomalayan, New Zealand (Sandlant, 2002), Eastern Asian regions, United Kingdom and some parts of the Middle East (Bram, 1967). Weinstein (1997) reported that the female vector of *Cx. quinquefasciatus* are nocturnal in biting nature and laid its eggs in rafts form on water surface of artificial container. It can bite man (indoor and outdoor) as well as other group of animals (Holder *et al.,* 1999; Lee *et al.,* 1989).

Owing to the harmful effect of the disease transmitted by mosquitoes, the control of these diseases (dengue, filariasis, malaria etc) is essential for public health which depends on the controlling methods of their larval stages through spraying larvicides because it is easy to handle their larval form of mosquitoes than the adult form. According to Brown (1986) and Russell (2009) continuous use of chemical insecticide spread some toxic substances in environment which affect the food chain of animals and the quality of environment which are harmful to human and non-targeting organisms also (Nayak and Mohan, 2015). So, for the control of the continuous use of chemicals the Environmental Protection Act (1969) had framed some rules and regulations (Bhatt and Khanal, 2009). Therefore, it has been necessary to search alternative methods to control mosquito larval using safe, low cost and ecofriendly methods. Thus the biological control of mosquito vectors had found an alternative for the environment than chemical insecticide.

Herbal insecticide could be positively associated to interrupt the transmission of these dreadful diseases for the community. From the ancient times different kind of toxic substances from the plants had been used to control the pest which is cheap in cost, biodegradable

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and ecofriendly in nature. Some countries used botanical insecticide like Pyrethrum, Nicotine, Derris, Quassia, Hellebore, Azadirachtin, Anabasine, d-limonene camphor, Turpentine, Chrysanthemum (Rahuman *et al.,* 2008). In early 1933, medicinal plants were explored having larvicidal properties used for the vector control (Debella *et al.,* 2007; Huang and Ho, 1998). According to Pitasawat *et al*., 2007 plant products might be a better option in order to control the growth of mosquito vectors which develop the interest among researchers to use the phytochemicals as an antimalarial agent. Recently numerous scientific reports had been published on control of vector species of mosquitoes (Sukumar *et al.,*1991; Shaalan *et al.,*2005; Omena *et al.,*2007; Fallatah and Khater, 2010; Pohlit *et al.,* 2011 and Ghosh *et al.,* 2012).

Larvicidal Activity of Botanical Extracts

Benelli (2017) indicated in his study that different kind of chemical compounds found in larvicides, maintain resistance development in targets as a result of various biological mechanism. Sukumar *et al.,* 1991 observed 344 plant species showing mosquitocidal activity while Shaalan *et al.,* 2005 and Ghosh *et al.,* 2012 reviewed the current state of knowledge about the physiological and phyto-chemical process of the larvicidal plants (Table1).

The botanical insecticides, formulated using floral resources, exhibit their larvicidal activity due to their phytochemicals. So many phytochemicals as steroids, essential oils, alkaloids and phenolics have been extensively studied in recent years for their insecticidal properties. Shaalan *et al.* (2005) reported that the insecticidal properties of the plant species are also dependent on their solvent extraction methodology.

Indigenous Plants having Larvicidal Properties against Dengue Vector

This review is also comprising of, existing studies on various commonly occurring indigenous plants showing mosquito larvicidal activity (Table 1). Kamalakannan *et al.,* 2011 determined the biological activities of methanol extracts of *Acalypha indica* and *Achyranthes aspera* leaves against *Ae. aegypti*. According to the study leaf extract showed the highest LC_{50} values at 277ppm which concluded the strongest larvicidal activity. Similarly, Viji and Nethaji in 2015 observed the mortality effect of ethanol extracts of *Acorus calamus* against *Ae. aegypti* at 0.500 mg/ml concentration. Subramaniam *et al.,* 2012 observed that the LC_{50} value against the different stages of *Ae. aegypti*. (1^{st} to 4^{th}) were 162.74, 201.43, 253.30 and 300.05 ppm and the LC_{90} 442.98, 518.86, 563.18 and 612.96 ppm, respectively while Susheela *et al.,* 2016 observed the moderate efficacy of *Aloe vera* and *Onion* extract against *Ae. aegypti*. Govindarajulu *et al.,* 2015 studied on the Fourier Transform Infra-Red spectroscopy (FTIR) and found to be 100% larvicidal activity with LC_{50} values were 9.96 and 6.918 mg/L with its ethanol and methanol extracts against *Ae. aegypti*. Govindarajan (2009) reported the larvicidal, ovicidal and repellent activity of different leaf extracts with different solvents (methanol, benzene and acetone) against *Ae. aegypti* and the LC_{50} values were observed at 10.69, 18.27 and 23.95 mg/L, respectively. Jawale *et al.,* 2010 evaluated the methanol extract against *Ae. aegypti* and found 100% larval mortality in the 45µg/mL (soxhlet) and 25µg/mL (percolation) concentration and the LC_{50} value were found 14µg/mL and 6µg/mL respectively. Sharma *et al.,* 2005 tested larvicidal efficacy of *Citrus limon, Jatropha curcas, Ricinus communis, Lantana camara, Musa sapientum, Syzygium camini* and *Ficus bengalensis* against *Ae. aegypti* and resulted 100 percent mortality. Warikoo *et al.,* 2012 tested the hexane extract of this plant with 24 hrs exposure against 4th instars of *Ae. aegypti* and found LC_{50} value at 446.84 ppm. Viji and Nethaji (2015) studied on rhizome extract of *C. longa* against *Ae. aegypti* and found 100% mortality at conc. of 0.500 mg/ml. Srinivasan *et al.,* 2015 was found to be LC_{50} 3.1870 and LC_{90} 5.3991 against the larvae of *Ae. aegypti* after 24hrs. Singh *et al.,* 2003 reported the larvicidal properties of leaves extract of *O. canum* and the LC_{50} values were found to be for 2^{nd}, 3^{rd} and 4^{th} larvae of *Ae. aegypti* were 177.82, 229.08 and 331.13 ppm respectively. Krishan *et al.,* 2008 assessed the bioactive saponin isolated from this plant and was tested against 2^{nd} and 4^{th} instar larvae of *Ae. aegypti* with different concentrations and the LC_{50} value was found to be 150.79 ppm for 4^{th} instar larvae and 240.10 ppm for second instar larvae. Patil *et al.,* 2011 tested the larvicidal activity of *Pl. zeylanica* and *Cestrum nocturnum* against the different stages larvae of *Ae. aegypti* and found LC_{50} values on less than 50ppm conc., the stability was found to be increased with the constant temperature (19°C, 22°C, 25°C, 28°C, and 31°C). Murthy and Rani (2009) tested larvicidal activity of acetone extracts of buds of many plants like *Piper cubeba, Capparis spinosa, Syzygium cumini, Nerium indicum, Millingtonia hortensis,, Delonix regia, Limonia acidissima* and *J. curcas* against *Ae. aegypti*. The acetone extracts of *D. regia* and *L. acidissima* were showed 100% toxicity than *P. cubeba* and *C. spinosa.* Chowdhury *et al.,* 2008 tested the aqueous and solvents with berries of this plant and after 72 hrs the aqueous extract was found with highest mortality at 0.5% against dengue vector *Stegomyia aegypti*.

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Table 1.Efficacy of Plant Extracts against Different Species of Mosquitoes

S. No.	Plant botanical name	Common name	Family	Plant part used	Target mosquito species	Mechanism of action as a larvicide	Result	Reference
1.	*Acalypha indica*	Indian mercury	Euphorbiaceae	Leaves	*Ae. aegypti*	NA	LC_{50} values were 409 ppm	Kamalakannan *et al.* (2011)
2.	*Achyranthes aspera*	Chaff-flower	Amaranthaceae	Leaves	*Ae. aegypti* and *Cx. Quinquefasciatus*	NA	LC_{50} value of 18.20 and 27.24 ppm against *Ae. aegypti* and *Cx. quinquefasciatus*	Bagavan *et al.* (2008)
3.	*Acorus calamus*	Acoraceae	Sweet flag or calamus	Leaves	*Ae. aegypti*	NA	LC_{50} values was 0.500 mg/ml	Viji S and Nethaji S (2015)
4.	*Aegle marmelos*	Bael	Rutaceae	Leaves	*An. subpictus* & *Cx. Tritaeniorhynchus*	NA	LC_{50} value were 167	Elango *et al.* (2009)
5.	*Agave Americana*	Century plant	Agavaceae	Leaves	*An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti.*	NA	100% mortality for *An.* and *Ae.*, 56% for *Cx.* spp.	Dharamshaktu *et al.* (1987)
6.	*Agave sisalana*	Asparagaceae	Sisal hemp	Leaves	*An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti*	NA	LC_{50} value of dried crude, methanol and petroleum ether against *An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti* were 75, 86 & 76 ppm; 36, 82 & 220 ppm and 27, 51 & 31 ppm, respectively.	Singh *et al.*(2014)
7.	*Ageratina adenophora*	Crofton weed	Asteraceae	Leaves	*Ae. aegypti, Cx. Quinquefasciatus*	NA	LC_{50}value were 356.70 ppm for *Ae. aegypti* and 227.20 ppm for *Cx. quinquefasciatus*.	Rajmohan and Rama swamy (2007)
8.	*Aloe vera*	Aloe	Asphodelaceae	Leaves	*Ae. aegypti*	NA	89% mortality on 1st instar & 75% on 3rd instar	Subramaniam *et al.* (2012)
9.	*Annona reticulate*	Annonaceae	Custard apple	Leaves	*Ae. aegypti*	NA	LC_{50} values were 9.96 and 6.918 mg/ L with reference to ethanol and methanol extracts	Govindarajulu *et al.* (2015)

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10.	*Azadirachta indica*	Neem	Meliaceae	Leaves	*An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti*	NA	LC_{50} values were 0.046, 0.208, and 0.866 ppm against *An. stephensi, Cx. quinquefasciatus*and *Ae. aegypti,* respectively.	Gunasekaran *et al*. (2009)
11.	*Cannabis sativa*	Bhang	Cannabaceae	Leaves	*An. stephensi*	NA	LC_{50} values were 88.51ppm	Maurya *et al.* (2008)
12.	*Cassia occidentalis*	Chakunda, coffee senna	Caesalpiniaceae	Leaves & stem	*Ae.aegypti*	NA	100% mortility in hexane extract	Sharma A, Kumar S and Tripathi P (2016)
13.	*Calotropis procera*	Sodom apple, rubber bush	Asclepiadaceae	Leaves	*An. stephensi* and *Cx. Quinquefasciatus*	NA	LC_{50} values were 109.71 and 387.93 mg/l against *An.* and *Cx.* respectively	Shahi *et al.* (2010)
14.	*Catharanthus roseus*	Periwinkle, sadabahar	Apocynaceae	Leaves & stem	*Ae.aegypti*	NA	LC_{50} values were 86.913	Sharma A, Kumar S and Tripathi P (2016)
15.	*Cassia fistula* Linn.	Golden rain tree	Leguminosae	Leaves	*Ae. aegypti*	NA	LC_{50} value of methanol, benzene and acetone were 10.69, 18.27 and 23.95 mg/L, respectively	Govindarajan M (2009)
16.	*Cestrum nocturnum*	Night-blooming jasmine	Solanaceae	Leaves	*Ae. aegypti*	NA	LC_{50} of methanol extract and active fraction were found 14µg/mL and 6µg/mL respectively	Jawale *et al.* (2010)
17.	*Clitoria ternatea*	Butterfly pea	Fabaceae	Seeds	*An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti*	NA	LC_{50} values of methanol extracts were 65.2, 154.5 and 54.4 ppm against *An. stephensi, Ae. aegypti* and *Cx. quinquefasciatus* respectively	Mathew *et al.* (2009)
18.	*Citrus limon*	Lemon	Rutaceae	Leaves	*Ae. aegypti, An. stephensi and Cx. Quinquefasciatus*	NA	100 percent mortality	Sharma AK, Baruah K and Bhardwaj AC (2005)

19.	*Citrus limetta*	Mousambi	Rutaceae	Peel	*An. stephensi* and *Ae. aegypti*	NA	LC_{50} values were 132.45 and 96.15 ppm, respectively	Kumar S,Warikoo R., Mishra M, Seth A and Wahab N (2011)
20.	*Citrus sinensis*	Orange	Rutaceae	Leaves	*Ae. aegypti*	NA	LC_{50} values was 446.84 ppm	Warikoo *et al.* (2012)
21.	*Curcuma longa*	Zingiberaceae	Turmeric	Rhizome	*Ae. aegypti*	NA	LC_{50} value 0.500 mg/ml	Viji and Nethaji S (2015)
22.	*Eichhornia crassipes*	*Water hyacinth*	Pontederiaceae	Leaves	*Cx.quinquefasciatus*	NA	LC_{50} values were 80.54 and 135.70 mg/Lr in hexane and methanol	Annie (2015)
23.	*Eucalyptus citriodora*	Lemon-scented eucalyptus	Myrtaceae	Leaves	*Cx. quinquefasciatus, Ae.aegypti* and *An. stephensi*	NA	LC_{50} values were 69.86, 81.12 & 91.76 ppm respectively	Singh RK, Dhiman RC and Mittal PK (2007)
24.	*Feronia limonia*	Wood apple	Rutaceae	Leaves	*Cx. quinquefasciatus, An. stephensi* and *Ae. aegypti*	NA	LC_{50} values were 129.24, 7.58 and 57.23 ppm against *Cx. quinquefasciatus, An. stephensi* and *Ae. aegypti* respectively	Rahuman *et al.* (2000)
25.	*Feronia limonia*	Elephant apple, wood apple	Rutaceae	Leaves	*An. stephensi, Ae. aegypti, Cx. Quinquefasciatus*	NA	LC_{50} value 15.03ppm against *An. stephensi*, 11.59 ppm of *Ae.* aegypti and 22.49 ppm of *Cx. quinquefasciatus*	Senthilkumar *et al.* (2013)
26.	*Impatiens balsamina*	Balsaminaceae	Garden balsam, garden jewel weed	Leaves	*An. stephensi*, *Ae. aegypti* and *Cx. Quinquefasciatus*	NA	LC_{50} values of crude benzene, chloroform, ethyl acetate and methanol against *An. stephensi*, *Ae. aegypti* and *Cx. quinquefasciatus* were 98.04, 119.68 and 125.06 mg/l respectively	Govindarajan M and Rajeswary M (2014)
27.	*Indigofera tinctoria*	Fabaceae	True indigo	Leaves	*Aedes aegypti*	NA	LC_{50} value 3.1870	Srinivasan *et al.* (2015)

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28.	*Ipomoea cairica*	Cairo morning glory	Convovulaceae	Whole plant	*Cx. tritaeniorhynchus, Ae. aegypti, An. stephensi and Cx. Quinquefasciatus*	NA	LC_{50}value were 14.8 and 78.3, 22.3 and 92.7, 14.9 and 109.9, 58.9 and 161.6 ppm respectively against *Cx. tritaeniorhynchus, Ae. aegypti, An. stephensi and Cx. quinquefasciatus*	Thomas TG, Rao S and (2004)
29.	*Lantana camara*	Big-sage	Verbnaceae	Leaves and flowers	*Ae. aegypti* and *Cx. Quinquefasciatus*	NA	maximum mortality was observed at 1mg/ml in *Ae. aegypti* and 3mg/ml in *Cx. quinquefasciatus*	Sathish K, Maneemegalai S (2008)
30.	*Lantana camara*	Spanish flag, wild Sage	Verbenaceae	Leaves	*Cx. quinquefasciatus, Ae. aegypti* and *An. stephensi.*	NA	100% mortality in six hours.	Rajan and Varghese (2017)
31.	*Limonia acidissima*	Elephant apple	Rutaceae	Leaves and florals	*Ae.aegypti*	NA	Extracts shows toxicity up to 100 %.	Murthy and Rani (2009)
32.	*Mentha piperita*	Peppermint	Lamiaceae	Leaves	*Ae. aegypti*	NA	LC_{50} value was 111.9 ppm	Sarita *et al.* (2011)
33.	*Momordica charantia*	Karela	Cucurbitaceae	Fruit	*Ae. aegypti, An. stephensi* and *Cx. Quinquefasciatus*	NA	LC_{50} value was 122.45 in hexane extract	Singh *et al.* 2006
34.	*Nyctanthes arbortristis*	Night-flowering Jasmine	Oleaceae	Leaves and flowers	*An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti*	NA	The LC_{50} values of chloroform extract of leaves were 303.2, 518.2, and 420.2 ppm against *Ae. aegypti*, *An. stephensi*, and *Cx.quinquefasciatus* respectively	Mathew N *et al.* (2009)
35.	*Ocimum canum*	Mint	Lamiaceae	Leaves	*Ae. aegypti*	NA	LC_{50} values for 2nd, 3rd and 4th larvae were 177.82, 229.08 and 331.13 ppm respectively	Singh NP, Kumari V and Chauhan D (2003)
36.	*Ocimum sanctum*	Tulsi	Lamiaceae	Leaves	*Ae.aegypti* and *Cx. Quinquefasciatus*	NA	LC_{50} value was 425.94 ppm in acetone	Anees AM. 2008

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37.	*Plumbago zeylanica*	Ceylon leadwort	Plumbaginaceae	Whole plant	*Ae. aegypti*	NA	The LC_{50} values were less than 50 ppm (15.40-38.50 ppm) against all tested larval instars	Patil *et al.* (2011)
38.	*Pongamia glabra*	Pongam tree	Fabaceae	Seed	*Cx. quinquefasciatus*	NA	54% Mortality at 1,000ppm	Rahuman *et al.* (2008)
39.	*Ricinus communis*	Castorbean	Euphorbiaceae	Seed	*Cx. quinquefasciatus, An. stephensi* and *Ae. albopictus*	through histopathological changes (Aouinty *et al.* 2018)	LC_{50} values were 7.10, 11.64 and 16.84 µg/mL respectively	Mandal S *et al.* (2010)
40.	*Solanum nigrum*	Black nightshade,	Solanaceae	Dried fruit	*An. culicifacies, An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti*	NA	All species shows 100 per cent mortality in larval bioassays at 1000 ppm with aqueous extract.	Raghavendra *et al.* (2009)
41.	*Solanum villosum*	Hairy nightshade	Solanaceae	Berries	*St. aegypti*	NA	Chlororm and methanol extract having 70% mortality and 40% mortality respectively.	Chowdhury N, Ghosh A and Chandra G (2008)
42.	*Tagetes patula*	French marigold	Asteraceae	Essential oil	*Ae. aegypti, An. stephensi and Cx. Quinquefasciatus*	NA	LC_{50}value were13.57, 12.08 and 22.33 against *Ae. aegypti, An. stephensi* and *Cx. quinnquefaciatus* respectively	Dharmagaddae*t al.* (2005)
43.	*Tribulus terrestris*	Goat'shead	Zygophyllaceae	Leaves and seeds	*An. culicifacies, An. stephensi,Cx. quinquefasciatus* and *Ae. aegypti*	NA	LC_{50} value of leaves extract against *An. culicifacies*, *An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti* were 117, 124, 168 and 185 ppm respectively and 100, 72, 91 and 91 ppm respectively of seed acetone extract.	Singh *et al.* (2008)
44.	*Tridex procumbens*	Coatbuttons	Asteraceae	Leaves	*Ae. aegypti*	NA	LC_{50} value were 150.79 ppm for fourth instar larvae and 240.10 ppm for second instar larvae	Krishan V, Jyoti C and Saxena R.C (2008)

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45.	*Toddalia asiatica*	Orange climber	Rutaceae	Fruits and leaves	*Cx. quinquefasciatus, Ae. aegypti*	NA	LC_{50} value of hexane, acetone and methanol extracts of fruits against *Ae. aegypti* were 37.23, 50.69 and 125.55 ppm and against *Cx. quinquefasciatus* were 33.23, 82.20 and 215.19 ppm, respectively. In leaves LC_{50} values against *Ae. aegypti* were 133.80, 177.20, 79.48 and against *Cx. quinquefasciatus* were 164.53, 175.28 and 87.87 ppm, respectively	Borah R *et al.* (2010)
46.	*Thevetia peruviana*	Apocynaceae	Yellow oleander	Leaves	*An.stephensi* and *Ae. aegypti*	NA	LC_{50} values of the petroleum ether, chloroform, acetone and methanol against *An.stephensi* and *Ae. aegypti* mosquitoes were 0.045, >0.05, 0.026, 0041 and 0.038, >0.05, 0.021 and 0.036%, respectively.	Yadav S, Singh and Mittal (2013)
47.	*Withania somnifera*	*Ashwagandha*	Solanaceae	Fruit, seed, leaves and root	*An. stephensi, Ae. aegypti* and *Cx. Quinquefasciatus*	NA	LC_{50} values for seeds in acetone, methanol and petroleum ether were 188.1, 777.5, 822.5; 245.5, 769.0, 1169.0; 140.3, 822.9, 778.4 and for fruit without seeds were 80.2, 97.6, 146.6; 88.4, 404.4, 1030.0; 30.0, 44.5, 54.2 mg	Bansal *et al.* (2011)
48.	*Xanthium strumarium*	Clotbur	Asteraceae	Leaves	*An. culicifacies, An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti.*	NA	LD_{50} value of ethanol extract were 0.19, 0.8, 0.27, 0.27%	Singh *et al.* (2009)
49.	*Zanthoxylum armatum*	Prickly ash and Hercules club	Rutaceae	Essential oil	*Cx. quinquefasciatus, Ae.aegypti* and *An. stephensi*	NA	LC_{50} values were 49 ppm, 54-58 ppm respectively against *Cx. quinquefasciatus, Ae.aegypti* and *An. stephensi*	Tiwary *et al.* (2007)

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Common Indigenous Plants having Larvicidal Properties

There were so many plants which showed larvicidal properties against different vector species of mosquitoes. Gunasekaran *et al.,* 2009 also reported in the study neem formulation of 0.046, 0.208 and 0.866 ppm were found to show the mortality against *An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti,* respectively. Bagavan *et al.,* 2008 studied on isolated compound of ethyl acetate extract of *Achyranthes aspera* and found LC_{50} value of 18.20 and 27.24 ppm against *Ae. aegypti* and *Cx. quinquefasciatus*. Dharmshaktu *et al.,* 1987 also extracted leaves of *Agave americana* and tested against three mosquito species *Anopheles, Aedes* and *Culex* and found 100% mortality within 24-48 hours at a concentration of 0.0032% for *Ae. aegypti*, 0.016% for *Cx. quinquefasciatus* and 0.08% for *An. stephensi*. Singh *et al.,* 2014 tested the extract of *Ag. sisalana* against *An. stephensi*, *Cx. quinquefasciatus* and *Ae. aegypti* and found the LC_{50} value of petroleum ether, dried crude and methanol extracts were 75, 86 & 76 ppm; 36, 82 & 220 ppm and 27, 51 & 31 ppm, respectively. Rajmohan and Ramaswamy (2007) observed the larval mortality against *Ae. aegypti* and *Cx. quinquefasciatus* were separately in control at different concentrations, according to the Probit analysis, the 24 hrs LC_{50} value was found 356.70 ppm for *Ae. aegypti* and 227.20 ppm for *Cx. quinquefasciatus*. Kumar *et al.,* 2011 found that the peel of extracted of *C. limetta* in hexane solvent having significant mosquito larvicidal properties against *An. stephensi* and *Ae. aegypti* and LC_{50} values was 132.45 and 96.15 ppm, respectively. Shahia *et al.,* 2010 concluded the value of LC_{50} were 109.71 and 387.93 mg/l against *An. stephensi* and *Cx. quinquefasciatus.* Similarly, Singh *et al.,* 2005 was also found to be more effective larvicide of methanolic extracts and dresh leaf extract of this plant against *An. stephensi*, *Cx. quinquefasciatus* and *Ae. aegypti*. Mathew *et al.,* 2009 screened the three plants *Saraca indica/asoca, Nyctanthes arbor-tristis* and *Cl. ternatea* which having potential larvicidal properties against *Ae. aegypti*, *Cx. quinquefasciatus* and *An. stephensi.* The LC_{50}values was found 154.5 ppm, 54.4 ppm and 65.2 ppm against these three vectors respectively with the methanol extracts of leaves, flowers and seed extracts. Singh *et al.,* 2007 tested the hexane extract against the larvae of *An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti* and found the better larvicidal properties of hexane extract of leaves of *Eu. citridora* against *An. stephensi* and LC_{50} values were 69.86, 81.12 & 91.76 ppm respectively. Rahuman *et al.,* 2000 reported the LC_{50} values of *F. limonia* are 129.24, 7.58 and 57.23 ppm against *Cx. quinquefasciatus, An. stephensi* and *Ae. aegypti* respectively while Senthilkumar *et al.,* 2013 resulted LC_{50} 15.03 and LC_{90} 36.69 ppm against *An. stephensi*, LC_{50} 11.59 and LC_{90} 42.95 ppm against *Ae. aegypti* and LC_{50} 22.49 and LC_{90} 60.90 ppm against *Cx. quinquefasciatus*. Govindarajan and Rajeswary (2014) observed the better larvicidal potential of methanol extract of leaves with LC_{50} values of 98.04, 119.68 and 125.06 mg/l, respectively against larvae of *An. stephensi*, *Ae. aegypti* and *Cx. quinquefasciatus.* Thomas *et al.,* 2004 tested the essential oil against the larvae of *Cx. tritaeniorhynchus* (100 ppm), *Ae. aegypti* (120 ppm), *An. stephensi* (120 ppm), and *Cx. quinquefasciatus* (170 ppm) from 100 to 170 ppm conc. The LC_{50} and LC_{90}values were found for *Cx. tritaeniorhynchus*, *Ae. aegypti*, *An. stephensi*, and *Cx. quinquefasciatus* 14.8 and 78.3, 22.3 and 92.7, 14.9 and 109.9, and 58.9 and 161.6 ppm, respectively. Kumar and Maneemegalai (2008) evaluated the methanol and ethanol extract of flowers and leaves of *L. camara* against larvae of *Ae. aegypti* and *Cx. quinquefasciatus* with the maximum mortality of 1.0 mg/ml. Singh *et al.,* 2006 investigated the crude aqueous and hexane extracts against *An. stephensi*, *Cx. quinquefasciatus* and *Ae. aegypti* respectively and found the LC_{50} values 0.50, 1.29 and 1.45% with aqueous extracts and 66.05, 96.11 and122.45ppm respectively with hexane extracts. Anees (2008) tested the leaves extract of *O. sanctum* against *Ae. aegypti* and *Cx. quinquefasciatus* and the highest LC_{50} value was 425.94 ppm in acetone while Khare *et al.,* 2017 was found 100% larval mortality in the leaf and stem ethanolic extract against *An. subpictus* and *Cx. tritaeniorhynchus.* Rahuman *et al.,* 2008 observed that the lethal concentration 50 and 90 value of *P. pinnata* against the 4th instar larvae were 0.8943 and 1.1694ppm against *Ae. aegypti* and *Cx. quinquefasciatus* while shows higher effect than crude solvent. Mandal (2010) exhibited the 100% killing activities of seed extract at conc. 32-64 μg/mL with LC_{50} values 7.10, 11.64 and 16.84 μg/mL for *Cx. quinquefasciatus, An. stephensi* and *Ae. albopictus* larvae respectively. Raghavendra *et al.,* 2009 tested the efficacy of the aqueous and hexane extracts of dried fruit of this plant against the five vector species *An. culicifacies A and C*, *An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti* with 100% mortality of aqueous extract at 1000 ppm and hexane extract at 100 ppm. Dharmagadda (2005) tested the five different concentrations of essential oil against the larvae of *Ae. aegypti*, *An. stephensi* and *Cx. quinquefasciatus* compared with malathion (synthetic insecticide) in which *Ae. aegypti* was found to be higher LC_{50} values 13.57, LC_{90} 37.91 than *An. stephensi* and *Cx. quinquefasciatus*. Yadav *et al.,* 2013 was found LC_{50} values of the petroleum ether, chloroform, acetone and methanol extracts against *An. stephensi* and *Ae. aegypti* were 0.045, >0.05, 0.026, 0041 and 0.038, >0.05, 0.021 and 0.036%, respectively (after 24hrs). Borah *et al.,* 2010 investigated the larvicidal potentiality of acetone, hexane and methanol extracts of fruits and leaves from this plant against the larvae of *Ae. aegypti* and *Cx. quinquefasciatus* in which hexane extract was showed highest larvicidal activity than other

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solvents. Singh *et al.*, 2008 tested the extract of acetone of leaves and seeds showed 100% mortality against *An. culicifacies*, *An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti* with 200ppm and the LC_{50} values of leaves acetone extract were observed after 24 hrs 117, 124, 168 and 185 ppm respectively while seed acetone extract estimated after 24 hrs were 100, 72, 91 and 91 ppm respectively. Bansal *et al.,* 2011 extracted the different parts of this plant such as green and red fruits, seeds, fruits without seeds, leaves and roots in different solvents against larvae of *An. stephensi, Ae. aegypti* and *Cx. quinquefasciatus* and resulted that the most effective part was fruit without seeds in petroleum ether. Singh *et al.,* 2009 investigated the larvicidal and repellent activities with ethanol extract of leaf and seed of *X. strumarium* against *An. culicifacies*, *An. stephensi*, *Cx. quinquefasciatus* and *Ae. aegypti*. By this bioassay the LD_{50} values of ethanol-extracted of leaf were estimated 0.19, 0.8, 0.27, 0.27% and 90 1.3, 1.3, 1.0, 1.8% and in respect of seed were 0.15, 0.9, 0.25, 0.23 and 1.5, 1.4, 1.7, 1.9% against *An. culicifacies, An. stephensi, Cx. quinquefasciatus* and *Ae. aegypti* respectively. It showed 100% repellency effect against *An. culicifacies, An. stephensi* and *Cx. quinquefasciatus* in 0h 1h, 2h 4h and 1h 2h 6h, at 10% concentration respectively. Tiwari *et al.,* 2007 concluded that the LC_{50} and LD_{90} values of 49 and 146 ppm of essential oil of this plant species against *Cx. quinquefasciatus* shows effective larvicidal potential.

Conclusion

There are numerous chemical insecticides available in the market to control mosquitoes but having side effects on humans such as headache, nausea, dizziness and vomiting, thereby, herbal larvicides have been gaining popularity among researchers day by day since these formulations are relatively safe, eco-friendly, low in cost, easily available and best alternative to the organic synthetic larvicides. Several larvicidal compounds in plants have been identified as a result of employing various extraction procedures followed by structural determination and authentication using spectroscopy and chromatography tools. The review has been done in present study to gather the information available on effective plants for larvicidal activity however there is no pertinent information available on mechanism of action of active constituents from herbal plants whereby, the present review would be useful to promote the research aiming about the mechanism of action of the plant constitutes.

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