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Adulticidal and repellent properties of indigenous plant extracts against Larvae of mosquito: A Review

Nithar Ranjan Madhu[1] & Bhanumati Sarkar[2*]

[1]Department of Zoology, Acharya Prafulla Chandra College, New Barrackpur, West Bengal, India;
[2]Department of Botany, Acharya Prafulla Chandra College, New Barrackpur, West Bengal, India.

*Corresponding Author

Abstract

One method of prevention of mosquito borne diseases is the reduction of the mosquito population in the various stages of development, such as the use of ovicidal, larvicidal, pupicidal, adulticidal, and mosquitocidal substances. The application of chemical insecticides in mosquito control has resulted in the persistence and accumulation of non-biodegradable chemicals in the ecosystem, biological magnification through the food chain, insecticide resistance, and a toxic effect in human health and non-target organisms. Many studies on plant extracts against the mosquito population have been conducted around the world. The plant-mediated repellents are advantageous over chemical and physical methods, since it is cheap, single-step, and does not require high pressure, energy, temperature, or the use of highly toxic chemicals. In the latest years, a growing number of plant-borne compounds have been proposed for efficient and rapid extracellular synthesis of metal nanoparticles effective against mosquitoes at very low doses. The present study reveals that the aqueous extract of this leaf has a suitable property for a larvicidal natural product and may replace harmful chemical pesticides.

Introduction

Mosquitoes are vectors of many diseases, including malaria, filariasis, dengue, and Japanese encephalitis. Among these kinds of malaria, spread by the bite of female Anopheles mosquito, and filariasis, spread by *Culex* mosquito, are the two vector borne diseases of the tropical region and are considered major public health concerns. According to WHO, there were about 219 million cases of malaria in 2010 (with an uncertainty range of 154 million to 289 million) and an estimated 660,000 deaths (with an uncertainty range of 490,000 to 836,000). Malaria mortality rate has fallen by more than 25% globally since 2000 and by 33% in the WHO African region. Most deaths occur among children living in Africa, where malaria claims the life of a child every minute. Country-level burden estimates available for 2010 show that an estimated 80% of malaria deaths occur in just 14 countries and about 80% of cases occur in 17 countries. Together, the Democratic Republic of the Congo and Nigeria account for over 40% of the total estimated malaria deaths globally (WHO, 2013).

The recent outbreaks of Zika virus infections, occurring in South America, Central

America, and the Caribbean, represent the most recent of four arrivals of important arboviruses in the Western Hemisphere, over the last 20 years (Fauci and Morens, 2016). Zika virus follows dengue, West Nile virus and chikungunya (Benelli and Mehlhorn, 2016).

On the other hand, nearly, 1.4 billion people in 73 countries worldwide are threatened by lymphatic filariasis, commonly known as elephantiasis. Over 120 million people are currently infected, with about 40 million disfigured and incapacitated by the disease (WHO, 2013). Control or eradication of the mosquito population could significantly restrict the spread of disease.

Anopheles barbirostris is considered an important vector of malaria and Brugian filariasis in Sulawesi, Flores and Timor. Mosquitoes traditionally identified as *Anopheles barbirostris* are common and widely distributed from India through Mainland Southeast Asia and Southward through Indonesia to Sulawesi, all of the Lesser Sunda island chain to Timor Island and possibly the eastern fringe of the Maluku (Mollucas) archipelago (Harrison and Scanlon, 1975).

Culex quinquefasciatus is part of the Pipiens group and belong to the subgenus *Culex*. It is a medium, light brown mosquito, the abdominal sternites of the females are pale scaled with a few dark scaled patches medially. It is also an important vector of West Nile Virus (WNV) in some areas of the world. *Culex quinquefsciatus* is able to transmit Ross River Virus, Alfuy, Almpiwar, Corriparta, Dengue, Sindbis, Japanese Encephalitis virus Reticuloendotheliosis virus (Holder et al., 1999) and the protozoan, *Hepatozoon breini*, within the laboratory. *Culex quinquefasciatus* is also a laboratory host to a wide variety of other arboviruses including Murray Valley Encephalitis, Edge Hill, Eubenangee, Getah, Kokobera, Koongol, Kowanyama, Kunjin, Mapputta, Stratford, Trubanaman, Wongal, Reovirus type 3 and Chikungunya viruses (Holder et al., 1999). It is a domestic pest in many urban areas and often comes indoors at night to bite (Holder et al., 1999). It is also a major vector of bird pox and the avian malaria-causing protozoa and *P. cathemerium* (Lee et al., 1989).

The present study reveals that the aqueous extract of this leaf has a suitable property for a larvicidal natural product and may replace harmful chemical pesticides.

Chemical-based control measures

Insecticide-impregnated paint

To check the disease, extensive measures are made for mosquito control and more than 50,000 tons of chemical insecticides are used annually. These chemicals have nevertheless, considerable toxic and environmental risks. Use of pesticides can result in increase in contamination of soil and water. Being non selective, they kill together with the target insects, many beneficial organisms including the natural enemies of mosquito larvae, and disrupt the ecological balance. Mosquito control is facing a threat due to the emergence of resistance to synthetic insecticides (WHO, 2013).

Mosquito repellents

Nowadays, major prevention tools are represented by the employment of mosquito repellents [e.g., N,N-diethyl-meta-toluamide (DEET), dimethyl phthalate (DMP), N,N-diethyl mandelic acid amide (DEM), as well as plant-borne molecules] (Mehlhorn, 2015), light-colored clothes covering as much of the body as possible, and sleeping under mosquito nets (Benelli, 2015). People living in regions with endemic mosquito borne diseases should synergize these strategies with the reduction or removal of Culicidae breeding sites, as well as with mosquitocidal treatments using chemical or microbiological ovicides, larvicides and pupicides (Benelli, 2015). Therefore, novel and safer eco-friendly strategies to manage mosquito vectors are urgently needed.

Non-chemical based control measures

These nonionic, biologically degradable chemicals on application to mosquito breeding habitats spread spontaneously to form a monomolecular film on the water surface and exhibits mortality of mosquito larvae. Arosurf as SAA has been used effectively to control *Culex quinquefasciatus*, *Anopheles stephensi* and *Aedes aegypti* in different breeding habitats (cesspits, cesspools, drains and wells) (Das et al., 1986). Arosurf in combination with fast acting and residual larvicide (fenthion) enables better coverage of breeding habitats and long effective life of the film in inaccessible habitats like marshes and lagoons.

Insect growth regulators (IGRs)

Insect growth regulators (IGRs), the third generation insecticides, are diverse groups of chemical compounds that are highly active against larvae of mosquitoes and other insects. The IGRs in general have a good margin of safety to most non-target biota including invertebrates, fish, birds and other wildlife. They are also relatively safe to man and domestic animals. The IGR compounds do not induce quick mortality in the pre-imaginal stages treated and occur many days post treatment. This is indeed a desirable feature of a control agent because larvae of mosquitoes and other vectors are an important source of food for fish and wildlife. On account of these advantages of IGRs and the high level of activity against target species, it is likely that IGRs could play an important role in vector control programs in the future (Mulla, 1995). They are more specific for mosquitoes than conventional insecticides. The IGRs interfere with the hormonal mechanisms of target organisms and result in various kinds of morphological, anatomical and physiological abnormalities so that the target species does not reach the final stage of development (Amalraj et al., 1988). There is no likelihood of resistance development against these IGRs. A large number of IGRs, both juvenoids and chitin synthesis inhibitors, have been evaluated for the vector control but only very few of these are found effective and commercially feasible, e.g., diflubenzuron, methoprene, fenoxycarb (Tyagi et al., 1987). The IGRs have an added advantage of being used at a relatively very low dose compared to the conventional insecticides. Ecdysone agonists are hormonally active insect growth regulators that disrupt development of larvae and are found to be active against *Ae. aegypti*, *An. gambiae*, and *Cx. quinquefasciatus* (Beckage et al., 2004).

Biological control agents

Larvivorous fishes

Larvivorous fishes were the first biocontrol agents employed to control mosquito vectors. Fish have been used in many countries for malaria control by controlling vectors. Of these the common varieties utilized as biocontrol agents are the mosquito fish (*Gambusia affinis*), Guppies (*Poecilia reticulata*), *Aplocheilus blochii, Macropodus* and a variety of other local and indigenous fishes as per their availability in the local habitat. Many indigenous varieties of fishes are available and their larvivorous potential has been studied. In different countries the local fishes available have been explored to exploit their use against Anopheline and Culicine larvae. The ability of 2 freshwater fishes, eastern rainbow fish *Melanotaenia* *splendida* and flies pecked hardy head *Craterocephalus stercusmuscarum*, native to North Queensland to prey on immature *Ae. aegypti* was evaluated (Russel et al., 2001). Larvivorous fish Oreochromis spilurus was found to be effective against malaria vectors in Somalia (Mohamed, 2003).

Synthetic, microbial and plant-borne mosquitocides

Concerning the employment of synthetic pesticides, particular attention should be given to the development of mosquito resistant strains, as well as to environmental concerns (Naqqash et al., 2016). Indeed, in the past, Culicidae young instars have been massively targeted using organophosphates, carbamates and pyrethroids, with important negative effects on human health and the environment (Naqqash et al., 2016). Later on, insect growth regulators and microbial control agents have been introduced, and *Bacillus thuringiensis* var. *israelensis* is currently the most common mosquito larvicide employed in European countries. Its insecticidal activity was due to a parasporal crystal produced in the stationary phase of the bacterium growth cycle (Lacey, 2007). The crystal proteins (mainly composed by δ-endotoxin) dissolve in the midgut of the mosquito larval stage, where it is converted into toxic core fragments. The midgut epithelial cells rapidly swell and burst, causing the death of insect (Hofte and Whitely, 1989). Furthermore, the δ-endotoxins cause no harm to humans and non-target organisms. However, recent studies demonstrated that several pests, including mosquito, manifested resistance toward crystal proteins of *B. thuringiensis* var. *israelensis* (Naqqash et al., 2016). Due to the constraints highlighted above, a growing number of studies focused on the potential of plant-borne products are mosquito ovicides, larvicides and adulticides, as well as on their repellent and ovideterrent potential (Pavela and Benelli, 2016). In particular, Pavela (2015) evaluated the current research relying on essential oils as potential mosquito larvicides, showing that the most common families used for extraction of effective mosquitocidal essential oils are Lamiaceae, Cupressaceae, Rutaceae, Apiaceae, and Myrtaceae. Of 122 surveyed species, 77 showed LC_{50} < 50 ppm. Only seven essential oils (*Blumea densiflora*, *Auxemma glazioviana*, *Callitris glaucophylla*, *Cinnamomum microphyllum*, *Cinnamomum mollissimum*, *Cinnamomum rhyncophyllum* and *Zanthoxylum oxyphyllum*) showed LC_{50} < 10 ppm (Pavela, 2015), highlighting the promising potential of these essential oils and the related main constituents for the development of newer and effective control tools against mosquito young instars.

Green et al., (1991) observed mosquito adulticidal activity in the extract of *Tagetes minuta* flowers. The essential oil isolated from the plant was very much effective against *An. stephensi*. Growth inhibitory and juvenile hormone mimicing activity in the larvae of *Cx. quinquefasciatus* treated with acetone extracts of *Ageratum conyzoides*, *Cleome icosandra* and *Tridax procumbens* resulting in larval- pupal intermediates, demelanised pupae, defective egg rafts and adult with deformed flight muscles was described by Saxena et al., (1993). Loss of fecundity was also observed in the treated mosquito without any sterilant effect. Saxena et al., (1992) investigated on the whole plant extract of *Annona squamosa* (Annonaceae). The study revealed that alkaloid extracted from the plant have larvicidal, growth regulator and chemosterilant activity on *An. stephensi*. In Philippines, Monzon et al., (1994) investigated on the larvicidal potential of five plants against *Aedes aegypti* (L.) and *Cx. quinquefasciatus* (Say), and *Annona squamosa* and *Lansium domesticum* showed higher larvicidal potential against *Ae. aegypti* and *Cx. quinquefasciatus*. Perich et al., (1994) compared biocidal activities of the whole plant extracts of three tagete species and showed that *T. minuta* had the greatest biocidal activity on the larvae and adults of *Ae. aegypti* (L) and *An. Stephensi* (L). Bioassay of simultaneous steam distilled extracts of *T. minuta* flowers showed larval mortality and the corresponding $LC_{90.5}$ of 4 and 8 ppm against *Ae. aegypti* and *An. stephensi*, respectively. Chatterjee et al., (2008) investigated on the mortality patterns of fourth stage larvae of *C. vishnui* (group) and *An. subpictus* by the application of crude water extract of *Delphinium denudatum*. The 3% leaf extract brought 100% and 86.6% mortalities of *Cx. vishnui* and *An. subpictus* larvae respectively in 72 h indicating its efficacy as a strong larval toxicant.

Conclusion

Nowadays, parasitology is facing a number of crucial challenges, which mostly deal with the paucity of effective preventive and/or curative tools against malaria and arboviruses, with special reference to recent dengue, chikungunya and Zika virus outbreaks. In this scenario, the employment of botanicals and invertebrates as reducing, stabilizing and capping agents are advantageous over chemical and physical methods, since it is cheap, single-step, and does not require high pressure, energy, temperature, and the use of highly toxic chemicals. In addition, renewed efforts to standardize the chemical composition of botanical products used as sources of reducing and capping metabolites to develop large-scale production of eco-friendly mosquitocides.

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