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Green Methods to Combat Mosquitoes

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SUMMARY

Mosquitoes are one of the most noxious insects in the world. Mosquitoes are belonging to the genera *Anopheles*, *Culex*, *Aedes*, and several mosquito species from these genera cause several diseases like Malaria, Filariasis, Japanese Encephalitis, Dengue fever, yellow fever, etc. in human beings. There are many insecticides are being available for mosquito control in the market, but traditionally focused on killing mosquitoes using a variety of insecticides may lead to insecticide resistance in mosquitoes. Biological control methods are promising alternative methods to the chemical method. They include botanical insecticides, predators, releasing of sterile male mosquitoes, etc.

INTRODUCTION

Each year, about 300–500 million individuals in the globe are estimated to be affected by malaria, and this frightful disease threatens about 2.4 billion of the world's population with a death rate of about 1.1–2.7 million (WHO, 2005). A total of 404 species under 50 genera have been recorded in India (Tyagi *et al*., 2015). The major species that transmit diseases are *Anopheles culicifacies*, *An. stephensi*, *An. minimus*, *An. philippinensis*, *Aedes aegypti*, *Ae. albopictus*, *Culex tritaeniorhynchus*, *Cx. tarsalis*, *Cx. annulirostris*, *Cx. quinquefasciatus*, *Mansoniaindiana*, *M. annulifera*, and *M. uniformis* etc…

These diseases spread globally, causing high levels of human mortality and, they act as factors impediments to the economic development of most developing countries across the world. Vector control strategies have traditionally focused on killing mosquitoes using a variety of insecticides. As insecticide resistance is now widespread in several mosquito species, there is a growing need for safe novel, cheap, and reliable mosquito control strategies (Benelli, 2015). Biological methods provide promising alternatives to chemical control. They include natural organisms that kill mosquitoes, plant-based insecticides, releasing mosquitoes that are either sterile or unable to transmit disease as well as creating protective barriers against them.

Species transmitting diseases in India

Disease	Mosquito species
Dengue fever (DHF), Chikungunya, Zika, and yellow fever	*Ae. aegypti*
ilariasis, malaria	*Anopheles spp., Culex spp., Aedes spp.*
West Nile virus	*Culex sps.*
Japanese encephalitis	*Cx. tritaeniorhynchus*
Ross river fever	*Cx. annulirostris, Ae. vigilax, Ae. Notoscriptus*

I. Biological Methods

i) Entomopathogenic bacteria

Bacillus thuringiensis (Bt): *B. thuringiensis (Bt)* is a gram-positive, spore-forming, aerobic bacterium found in a multitude of habitats. Bt serovarieties with larvicidal activity for Lepidoptera, Coleoptera, Diptera, and other insects have been isolated from a diversity of habitats worldwide, including dead insects, soil, the phylloplane, grain dust, aquatic, and other habitats (Damgaard, 2000). The mosquitocidal bacterium *B. thuringiensis sub sp. israelensis* is highly effective than *B. sphaericus* as a larvicide against a wide range of mosquitoes and has been used routinely in many pest and vector control programs for more than 20 years

Mode of action *Bacillus thuringiensis israelensis* (Bti)

The principal insecticidal component of *B. thuringiensis subsp. israelensis* is a spherical parasporal body produced during sporulation and composed of four major endotoxin proteins, Cyt1Aa, Cry4Aa, Cry4Ba, and Cry11Aa. This parasporal body is one of the most insecticidal known, with (an LC50) value of 10 ng mL^{-1} against fourth instars of various mosquito species. Shortly after ingestion, these proteins bind to and lyse insect midgut epithelial cells which leads to death. Ingestion of activated toxic protein (granular formulation) of Bti was highly toxic to *Anopheles*, *Culex,* and *Aedes* larvae leading to the destruction of the cell membrane lining of the midgut. *Bt israelensis* @ 0.006 - 0.662 mg L^{-1} (LC50) caused 50 % mortality of *An. gambiae* (Boyce *et al*., 2013).

ii) Entomopathogenic fungi: These fungi do not cause instant mortality but cause sublethal and late-life lethal effects on different stages of the mosquito life cycle. Due to such properties, fungi can potentially be used as "evolution-proof" agents and overcome mosquito resistance unlike the currently deployed fast-acting chemical insecticides (Read *et al*., 2009). The common genera reported to affect mosquitoes are *Beauveria, Metarhizium, Leptolegnia, Pythium, Lagenidium, Coelomomyces*, and *Conidiobolus* of which *Beauveria* and *Metarhizium* are commonly used.

Mechanism of infection of EPF: In an adult mosquito, the conidia get attached to the host cuticle, forming an appressorium, followed by a penetration peg to enter the cuticle. After entering the hemocoel, hyphae are formed that produce and release toxins, killing the host within 4-16 days after contamination. In aquatic insect's fungal conidia enter through the spiracles, germinate, and penetrate the respiratory siphon, releasing toxins by blocking the breathing mechanism. When applied in water bodies, the hydrophobic conidia float on the water surface and encounter mosquito larvae through the tip of the siphon, and the head (Miranpuri and Khachatourians, 1991). When floating conidia meet the larvae, they break the water tension with their peri spiracular valves for air intake. Plugging of the spiracles usually leads to death before the significant invasion of the hemocoel has occurred, so hyphal body formation is minimum.

Commercial formulations of Bt used for mosquito control

1. Water Dispersible Granules (WDG)

VectoBac WDG: Application of (*Bt israelensis*) VectoBac WDG in stagnant water bodies @200 g/ha - 85.5% mortality, @ 400 gha^{-1} caused 94.1% mortality to *Cx. p. pipiens* adult population (Rydzanicz *et al*., 2009)

VectoLex WDG: Application (*B. sphaericus*) Vectolex WDG in stagnant water bodies @ 400-1600 gha^{-1} caused 67.7 - 69.9% mortality in larvae of *Cx. p. pipiens.*

2. Aqueous Suspensions (AS)

VectoBac 12AS: Application of VectoBac 12 AS (*B. sphaericus*) @ 500 mL ha^{-1} in stagnant water bodies @ 0.5 – 1L caused 91.9 % mortality of *Cx. p. pipiens* within 7 days (Rydzanicz *et al*., 2009)

3. Granules (G) Briquets: The FourStar™ briquets (*Bt israelensis*) 180-day formulation completely inhibited *An. gambiae* pupal production in the first 3 months, and reduced pupal productivity by 87–98%, 4-6 months after application (Afrane *et al*., 2016).

4. Icy granules: it is a new method of delivering the active ingredient, developed to overcome the disadvantages of loss of active agent during the application, sinking granules to the bottom of the breeding site due to weight, causing a need for increased dosages. The method involves creating a suspension of Bti powder and water and transforming it into ice pellets (named IcyPearls) using a special ice-making machine.

Predaceous insects: Natural enemies feeding on mosquito larvae and pupae in aquatic environments like copepods, odonate young instars, water bugs, amphibians, and fish

II. The Sterile Insect Technique

The Sterile Insect Technique (SIT) is a genetic suppression strategy that involves rearing large numbers of males of the target species and either irradiating or treating them with chemo-sterilizing agents to generate chromosomal aberrations and dominant lethal mutations in sperm. These sterilized male insects are released and when they mate with wild females produce no progeny. on a wider scale, for instance, country or continent-wide, unfeasible. The first major success was achieved against *Cx. quinquefasciatus* in Myanmar. In this project, mosquitoes sterilized by CI eliminated an isolated population of *Cx. quinquefasciatus.* Auto-dissemination was proposed recently to manage populations of *Aedes aegypti* and *Ae. albopictus* (Bonizzoni *et al*., 2013). The method is based on coating wild females with pyriproxyfen (PP), a

juvenile hormone analog (JHA), using dissemination stations. When contaminated females lay eggs in larval sites, the insect growth regulator prevents adult metamorphosis of all larvae, including those originating from other non -contaminated females. Auto-dissemination is limited by the low attractiveness of the dissemination stations for mosquitoes and a low range of action because the dispersal of the mosquitoes is below 1 km, which makes use.

III. Physical Methods

It is the modification of physical factors in the environment to minimize or prevent mosquito population which involves changing the water in the bird baths, pools, fountains, and rain barrels once a week. Screening of doors and windows to protect from the mosquito attack.

Mosquito net: These nets are considered more protective than coils and other repellents because their use does not cause any health problems. There are two types of nets such as **medicated nets** and **non-medicated nets**

Mosquito traps: These traps copy the various mosquito attractants such as body heat and exhaled carbon dioxide. They are powered by electricity so their use is safe.

IV. Mechanical Methods

Electric mosquito zipper: This device works by using ultraviolet light and then the killing of the mosquito occurs when the mosquito interacts with the lethal charge of the electric charge

Mosquito Magnet: Its principle is based on copying mammal properties such as giving off heat, moisture, and carbon dioxide. When a mosquito comes close to the device it drew in and suddenly dies.

CONCLUSION

Eco-friendly control methods for controlling mosquitoes are needed to reduce the continued application of insecticides that are presently used as the main method for mosquito control. Safe and sustainable methods using bioagents, predators, insect sterile techniques, and physical and mechanical methods should be developed to target numerous mosquito species in such a way that it is obtainable to the common man. Need-based production of biocontrol formulations in the form of tablets, capsules, icy granules, etc. should be publicized.

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