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Reducing Dengue Fever Through Biological Control of Disease Carrier Aedes Mosquitoes (Diptera: Culicidae)

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Abstract

Dengue is an infection that is carried by Aedes mosquitoes (Diptera: Culicidae) and can cause severe disease in peoples living in tropics. It is capable to cause headaches, pain and rash, and in other harsh types, may cause internal bleeding and then mortality of the patient. Currently, there is no vaccine for the treatment of dengue sickness and the most widely used methods for control of disease carrier Aedes mosquitoes are certain insecticides. These insecticides sometimes can harm the environment as well as peoples. For this reason, scientists are looking for better ways to prevent the spread of dengue disease by control of Aedes vector mosquitoes. Biological control of disease carrier Aedes mosquitoes is a suitable approach in Integrated Vector Management (IVM) program. Therefore, taking this objective into consideration, a broad biological control schedule is formulated based on the calendar of disease and vector's profile. The natural enemies of Aedes mosquitoes take part in a vital task to limit their densities in an area. Such natural enemies consist of predators, parasitoids and pathogens. Biological control of dengue carrier mosquitoes can be augmented by means of maintenance of existing natural enemies, establishing new natural enemies and setting up a permanent population, and mass culturing and intervallic release of natural enemies, whichever may be on a seasonal basis or else inundatively. Thus, when non-toxic biological control method is found to control a key vector, the reduced use of pesticides and increased survival of natural enemies frequently reduce the transmission of important mosquito's borne diseases in the community.

Keywords

Dengue, Mosquito, Biological Control, Predators, Parasitoids, Pathogens

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1. Introduction

Dengue is an infection that takes place within the tropics of the world and inside villages plus cities. This illness is also known as "break bone fever" for the reason that of the ache which may possibly happens in the joints of an infected person. The blood loss internally that occasionally follows repetitive infectivity may be lethal. The community seeks long-lasting and ecologically pleasant liberation from dengue occurrences (Sarwar, 2014 a). Dengue is reported to be the generally the quickly spreading mosquito borne disease in the world. Up to date estimates are that 50 million dengue infections occur each year, with 2.5 billion peoples at threat of infection in dengue endemic countries. Dengue distribution is extending across the tropics, but also reaches sub-tropical areas too (World Health Organisation, 2011).

The primary *Aedes aegypti* (Linnaeus) and secondary *Aedes albopictus* (Skuse) mosquitoes (Diptera: Culicidae) species are vectors of dengue fever and their origin include a forest habitat, and this might be as well the same for other vector

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species linked to the transmission of dengue in various parts of world including Asia and Africa. These vectors species in their natural habitat within the forest liked better plant stature and foliage-canopy by putting down eggs inside breeding locations of rainfalls gathered into the axils of plants and inside hollow trees. The jungle territory and tree-plant habitations are stable shaded sites, for this reason, these mosquito vectors demonstrate negative phototaxis for the duration of visual flight orientation as well as demonstrate precise likings to move or else rest in the directions of dark locations. This instinctive behavior made possible for these to become accustomed to stay alive in cottages or huts occupied by the ancient peoples. Now days, in under developed hot regions of the world, it is a widespread practice of the peoples to stock drinking water in utensils made up of mud or other matters that are placed inside otherwise near to their homes. These utensils are usually shadowy and comparatively cool those serve as an ideal substitution of the above cited hollow trees within a jungle as the larval breeding places. Such manmade containers characterize the conversion among the jungle and urban surroundings (Sarwar, 2014 b).

It comes into view that Aedes females are liable to settle indoors for the rationale that there are accessibility to the oviposition sites offered by manmade utensils as well as blood food from peoples, that permit for vectors to have a favorable stamina for consecutive generations inside the same family unit. As soon as further large human being settlements emerged, the vector become accustomed to water laying into containers like pots, buckets, old tires, etc., that are plentiful in the outdoor and indoor of homes within urban and rural constituencies. These situations provided an ideal site for lifecycle of Aedes mosquito to lead itself to the exploitation of these minute and manmade habitats for eggs survival against desiccation, and larval development habitats that potentially dry out. The Aedes mosquitoes are dynamic for the duration of the daytime, and as such they cannot be controlled using insecticide-treated bed nets contrary to the malaria vectors that can be controlled in the same way at night. Furthermore, it is becoming increasable imperative that these Aedes mosquitoes should be efficiently controlled using some other safer ways (Sarwar, 2014 c).

Plans prepared to check dengue by efforts to destroy the mature stage of the mosquitoes that transmits this illness are commonly unsuccessful for the reason that the adult stage of Aedes is the key type of vector which holds dengue virus, settles in rural and urban areas where that is not easy to locate and eradicate. Older tires and rubbish are the key spaces where these mosquitoes develop easily. In addition, the containers of drinking water are some other situates where these mosquitoes survive, and that cannot be polluted with potentially injurious substances. For these reasons, peoples seek to use biological control agents that are safer to use, do not hurt peoples and do not cost too much. Biological control means that public can utilize diverse types of living organisms known as biological control agents and other biological products, a lot of which can be spread by means of themselves that are not injurious to the surroundings (DeBach, 1991; Van Driesche and Bellows, 1996; Sarwar, 2013; Sarwar, 2014 d). Biological control is to make use of alive creatures to restrain insect vector populations and making them fewer injurious than they would otherwise can be. Biological control may be bring into play against all types of insects, including dengue vectors, however, the techniques and mediators employed are special for each type of vectors. This publication will focus here on the biological control of *A. aegypti* and *A. albopictus* mosquitoes. This information is aimed to explain the best ways to use such kind of interventions to keep peoples away from getting dengue fever.

2. Recognizing the Function of Natural Enemies of Mosquitoes

A variety of living things, still recognized as biological control mediators, can be exercised to thwart illnesses transmitted as a result of mosquitoes in lieu of lethal chemicals that may harm to the surroundings. Three are 3 groupings of natural enemies of mosquitoes i.e., predators, parasitoids and pathogens as discussed underneath.

2.1. Predators of Mosquitoes

Numerous diverse types of predators nourish on mosquitoes, which are an important component of the diet of a lot of invertebrates as well as vertebrates comprising insects, birds, amphibians, reptiles, fishes and mammals. These insectivorous invertebrates and vertebrates generally nourish on a lot of insect species, and often feed on mosquitoes especially when they are really plentiful. Insect and other arthropod predators are very frequently exercised in biological control for the reason that they predate on a lesser variety of victim species, as well as since arthropod predators, by means of their short life cycles, can change in density in reply to alterations in the population of their victim mosquitoes. Essential arthropod predators include insects that prey on mosquitoes which include dragonflies that are often referred to as mosquito hawks. One feature that favors dragonflies as mosquito predators is that the most of food of aquatic stage naiads is consists of mosquito larvae. While damselflies are not as effective in controlling mosquitoes as dragonflies, but their aquatic stage also consumes many mosquito larvae. Some mosquitoes that prey on other mosquitoes include notably the predatory mosquitoes in the genus Toxorhynchites. These mosquitoes provide a double benefit since the larvae are predacious on other mosquito larvae and the adults are not known to transmit disease. Both adult and larval species of aquatic beetles can consume mosquito larvae and pupae. Two beetles that readily eat the aquatic stages of mosquitoes are the predaceous diving beetle and the water scavenger beetles. Spiders become mosquito predator when a mosquito inadvertently flies into a spider's web where it is encased and eaten.

Another biological control agent that has been used to control mosquitoes is the deployment of fish that can eat the mosquito larvae and pupae. Fish can be incredibly effective at reducing Aedes mosquito numbers under field conditions. Goldfish, guppies, bass, bluegill and catfish prey on mosquito larvae. But the most important fish predator, by far, is the *Gambusia affinis*, commonly known as the mosquito fish. This is probably the most effective predator of mosquito larvae and is used by many mosquito control agencies to augment their control efforts. In a trial, the mean container index (CI) (percentage of water-holding containers infested with Aedes larvae or pupae) in cement tanks has been around 87% before indigenous fish species have been introduced, and then mosquito numbers recorded for a year. The results show that each of the 5 fish species eliminated mosquito breeding in the tanks, while the CI in the control remained at 86% (Martinez-Ibarra et al., 2002). Similarly, the Chinese cat fish *Clarias fuscus* reduced the Breteau Index (BI) (the number of positive containers per 100 houses) from 50 (before fish introduction) to 0 just within 15 days after fish introduction (Neng et al., 1987). In another trial, before the deployment of *Betta splendens* fish, 70.4% of the tanks have been infested with *A. aegypti*, one year later the infestation rate has been just 7.4% and dropping to 0.2% within 11 months later (Pamplona et al., 2004).

Most adult frogs and tadpoles infrequently feed on mosquito larvae, however, mosquito larvae predation is mainly known for three species such as spade foot toad, green tree frog and giant tree frog. Mosquito *A. aegypti* tends to lay eggs in anthropogenic refuse like water filled discarded plastic containers, tires, etc., which however can be controlled by removing them from the environment with many anti-dengue campaigns usually aim to do across the world. However, mosquitoes also lay eggs in ecologically sensitive natural sites, which are also used by frogs for breeding like tree holes, marshy areas, ponds and temporary pools, which cannot be removed from the environment. During the experiment, it has been found that the tadpoles fed on eggs such laid and frogs often lay eggs in such habitats (Bowatte et al., 2004). The red-eared slider turtle is generally thought to be the most voracious turtle that feeds on mosquito larvae.

Many bird predators usually eat both the adult and aquatic stages of mosquitoes, and the more important among these are purple martins, swallows, waterfowl (geese, terns and ducks) and migratory songbirds. Bats can eat mosquitoes, and these are far more effective at locating, catching and eating other prey insects as well.

2.2. Parasitoids of Mosquitoes

Parasitoids are natural enemies that by means of a juvenile phase which grows at or else inside a single mosquito and finally destroy the host. Their mature stages are normally free-living and can be predators of prey. Otherwise, these can as well take food from other resources, like as honeydew, plant nectar and plant pollen. For the reason that parasitoids ought to be adapted to the life cycle, bodily processes and defences of their hosts, they are restricted in their host array, and several are extremely specific for parasitism. Accordingly, a precise recognition of the parasitoid and host species is significantly essential in biological control for employing parasitoids. A gregarine protozoon parasite *Ascogregarina culicis* has been detected from the larvae of *A. aegypti* which can adversely affect the natural population of mosquito (John et al., 1995).

The scientists have infected mosquitoes with bacteria called *Wolbachia pipientis*, a parasite that can shorten the lives of dengue-infected mosquitoes. Instead of eradicating mosquitoes, the scientists aimed to use the bacteria to shift the age of the mosquito population. Although mosquitoes would still be around, yet these would have shorter life spans than they spend now. When a mosquito is infected with dengue, eight to twelve days must pass before the mosquito can infect another healthy person, and after that period, the mosquito can continue to infect peoples for the rest of its life, generally three to four weeks. If its life span is shorter, an infected mosquito would have fewer opportunities for dengue transmission (McMeniman et al., 2009).

2.3. Pathogens of Mosquitoes

Mosquitoes, similar to other insects, are contaminated by viruses, bacteria, fungi and protozoans which cause infection in the host. Such infection can decrease their rates of growth and feeding on human host, make sluggish or check their reproduction and even take their life. Additionally, mosquitoes are as well hit by a few types of nematodes which along with their bacterial symbionts, cause infection otherwise mortality of host. Under definite ecological circumstances, infection may proliferate and extend in nature all the way through mosquito populations, principally as soon as the density of the vector is elevated. An example of an established population of mosquitoes and pathogen which has been successfully controlling its host is the fungus

Entomophaga. The spores of fungus are believed to have been widespread and abundant, and continue to control vector populations for several years. The fungi overwinter as resting spores in soil or leaf litter that develop when vector populations are present. Probably, dispersing adults feeding in the tree canopy or larvae those come in contact to the soil, leaf litter or forest floor are most likely to be infected with spores. When there is satisfactory precipitation, and if the fungus in the bodies of these adults or larvae produces spores, these pathogens are spread to other life stages of vector. But, when the conditions are suitable, this infection cycle can occur again during the life stages of vector. The adult stages of Aedes specifically *A. albopictus* those rest on plant canopy or in forest litter are as well vulnerable to infectivity by sprouting resting fungus spores. When the infected mosquitoes die in large numbers, new resting spores are produced to survive in the subsequent generation. This biological control agent is believed to be reliant on rain at suitable times for the period of the breeding season for successfulness.

One potential method is the use of entomopathogenic fungi such as *Beauveria bassiana* (Bals.-Criv.) Vuill., and *Metarhizium anisopliae* (Metchnikoff) Sorokin. Infective spores of these fungi have been reported to affect larval and adult stages of mosquitoes, but a major limitation has been lack of persistence of the infective spore stage (Alves et al., 2002; Scholte et al., 2004). Other recent empirical studies demonstrate that fungal pathogens can infect insecticide resistant mosquitoes and reduce expression of insecticide resistance (Farenhorst et al., 2010), act synergistically with conventional interventions such as bed nets (Hancock et al., 2009) and chemical insecticides (Paula et al., 2010), highlighting the potential for using entomopathogenic fungi in novel integrated strategies for adult vectors control.

Just like those of humans, insect guts are full of microbes, and the microbiota can influence the insect's ability to transmit diseases. A new study reports that a bacterium isolated from the gut of Anopheles and Aedes can reduce infection of mosquitoes by malaria parasites and dengue virus. The bacterium can also directly inhibit these pathogens in the test tube and shorten the life span of the mosquitoes that transmit both diseases. The researchers have found that the pathogen bacterium Csp_P, a member of the family Chromobacteria, from the gut of *A. aegypti* and *Anopheles gambiae* (transmitter of malaria parasite *Plasmodium falciparum*) mosquitoes, through production of toxic metabolites, can inhibit growth of Plasmodium at various stages during the parasite's life cycle and also abolish dengue virus infectivity, and in addition Csp_P can inhibit growth of many other bacteria. Moreover, even without gut colonization, exposure to Csp_P through food or breeding water shortened the lifespan of adult mosquitoes and larvae of both species (Jose et al., 2010). The midgut of insect vectors of human disease contains not only pathogens harmful to human health, but also a diverse microbiota. This microbiota can influence insects' susceptibility to human pathogens, and the capacity to transmit them, through different mechanisms. Understanding the interaction between the vector, its microbiota and transmitted pathogens can provide novel opportunities to limit disease transmission (Nathan et al., 2014).

3. Using Biological Control of Mosquitoes in the Field

There are three key ways of using biological control of mosquitoes in the field, conservation of existing natural enemies, introducing new natural enemies (classical biological control) and establishing a permanent population by mass rearing and periodic release, either on a seasonal basis or inundatively.

3.1. Conservation of Existing Natural Enemies

Most natural enemies are highly susceptible to pesticides, and pesticide use is a major limitation to their effectiveness in the field. The original idea that inspired integrated pest management (IPM) is to combine biological and chemical control by reducing pesticide use to the minimum required for economic production, and applying the required pesticides in a manner that is least disruptive to biological control agents. The need for pesticides can be reduced by use of resistant varieties, cultural methods that reduce pest abundance or damage, methods of manipulating vector mating or host-finding behavior, and, in some cases, physical methods of control. Preventing of vector problems can be focused by greater understanding of its ecology, enhancing personal protection to defend against vector, and building populations of beneficial organisms, this is known as biointensive IVM.

3.1.1. Selecting and Using Pesticides to Minimize the Effect on Natural Enemies

The effect of a pesticide on natural enemy populations depends on the physiological effect of the chemical, how the pesticide is used and when it is applied. Among the insecticides, synthetic pyrethroids are among the most toxic chemicals to beneficials, while *Bacillus thuringiensis* and insect growth regulators are among the least toxic. The impact of pesticides on natural enemies can be reduced by careful timing and placement of applications to minimize contact between the beneficial organism and the pesticide.

Spot applications in the areas of high pest's density or treatment of alternating strips within a field may leave natural enemies in adjacent areas unaffected.

3.1.2. Providing Habitat and Resources for Natural Enemies

Some parasitoids and pathogens overwinter in the bodies of their hosts, but others may pass the winter in vegetation. Ground cover of vegetation provides shelter over the winter, refuge from pesticides used, source of pollen and alternate prey. The adults of many predators and parasitoids may require or benefit from pollen, nectar or so flowering plants may be needed as supplemental sources of pollen and nectar. Thus, diversification of plants or other methods of supplementing the nutrition of natural enemies must be done with knowledge of the behavior and biology of the natural enemy and vector.

3.2. Introducing New Natural Enemies and Establishing a Permanent Population

This process requires extensive research on the biology of the vector and potential natural enemies. After suitable natural enemies are found, studied and collected, then these must undergo quarantine to eliminate any pathogens or parasites present on the natural enemy populations. Afterward, the natural enemies are carefully released, with attention to proper timing in the enemy and pest life cycles, in a site where the target pest is abundant, and where disturbance of the newly released enemies is minimized. The most successful introductions of natural enemies include species of parasitoid and predator attacking larvae, adults and the eggs.

3.3. Mass Culture and Periodic Release of Natural Enemies

3.3.1. Seasonal Inoculative Release

Due to the weather or the lack of suitable hosts or prey, in some cases, a natural enemy is not able to overwinter successfully. Thus, particularly in highly disturbed systems, the natural enemy may need to be reintroduced regularly in order to maintain control of the vectors. Seasonal inoculative release of insect parasitoids and predators has been a highly successful strategy for biological control of the vectors. This strategy has adopted because of the prevalence of resistance of the vectors to insecticides and the rising costs of chemical control. The costs of using biological control are now much lower than using chemical control. Public can be informed about the details of implementation of the program, new developments, and new natural enemies through a network of extension advisers, specialized journals and grower study groups.

3.3.2. Inundative Release or Biological Insecticides

These two approaches are fundamentally different from all the other approaches of biological control because these do not aim to establish a population of natural enemies that multiplies to a level where it reaches a long-term balance with the population of its hosts or preys. Instead, the idea is to use biological agents like a pesticide to release in quantities that will knock down the pest population. Most commercially available formulations of insect pathogens are used inundatively.

Products formulates based on the bacteria *Bacillus sphaericus* and *Bacillus thuringiensis* are the best known examples of a biological insecticide to control larval populations at accessible costs and with no risk of pollution as threat to human and his environment. A Bacillus spray is essentially an insecticide which works by paralyzing the gut of the insect (depending on the strain used or mosquito). A protein produced by the bacterium is the active ingredient which paralyzes the gut, and in many products, there are no viable bacterial spores present, but just a formulation of the active protein. Thus, the disease does not continue to spread in the insect population. So far, there is no low-cost production of viruses with practical potential to be used against *A. aegypti* in developing countries; neither are there artificial cultures to produce the protozoans and microsporidians evaluated as parasites of the dengue vector.

The Toxorhynchites mosquitoes are good larval predators but high numbers of Aedes larvae are required to produce sufficient adults that need to be used in inundative releases. Their production although is easy, yet the strong cannibalism tendency is an obstacle for their mass production. Beneficial nematodes are an example of live natural enemies that are inundatively released. These nematodes travel either through the soil or on the soil surface, and actively attack their insect hosts. Just once inside the body, these release symbiotic bacteria, which multiply and kill the host. The nematodes feed on the bacteria and insect tissue, then mate and reproduce. After one to two weeks, new young nematodes emerge from the insect dead body to seek new hosts.

4. Conclusion

Mosquitoes have a number of natural enemies that collectively can exert some influence in reducing mosquito populations. However, with a very few exceptions, predators generally have little to moderate effects on reducing the mosquito population over a large area. All natural predators such as birds, dragonflies, bats, purple martins and others are playing a part in mosquito's control, but not to the extent that would be acceptable as a viable mean of vector control. This is true especially during times of extreme mosquito numbers after flooding or storm and when level of mosquitoes borne disease is higher. There are few instances where predators are quite efficient at controlling mosquito populations, although there are exceptions to the rule. The two prime examples are the canals and ponds, and the reason that it is often difficult to find mosquitoes breeding in these places is because these are usually permanent sources of water, and as such can support greater and varied concentrations of predators. Most of these predators are extremely beneficial in many other ways and should be protected and allowed a place in our rural and urban habitats. So, overall it is concluded that broad-spectrum properties of natural enemies together with their ability to kill mosquitoes can make them particularly interesting candidates for the development of novel control strategies against the most important vector borne diseases. Conversely, integrated vector management (IVM) is a comprehensive strategy which aims to achieve maximum negative impacts on vector borne diseases like dengue.

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