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Role of Secondary Dengue Vector Mosquito *Aedes albopictus* Skuse (Diptera: Culicidae) for Dengue Virus Transmission and Its Coping

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Abstract

Dengue is a viral infectious fever that is transmitted by Aedes mosquitoes (Diptera: Culicidae) causing a significant health burden in tropical countries since several decades. Severe complications such as dengue hemorrhage fever can develop and lead to fatal outcomes throughout the globe. Mosquito *Aedes albopictus* Skuse is an effective vector for dengue viruses both in its spread and transmission dynamics. The purpose of this study report is to explore an improved understanding of vector control and enhance dengue prevention. Ahead of tetravalent vaccine and drugs are available for dengue control, the vector control is the key component to manage dengue transmission. Vector control activities need to be guided by surveillance of outbreak and implement timely action to suppress dengue transmission and limit the risk of its further spread. Continual research on innovative ideas and tools for dengue surveillance and control can help to improve the effectiveness and efficiency of vector control in a nation. Legislation, such as the control of vector, pesticides acts and the environmental public health acts, and simultaneously discouraging persistent mosquito-breeding behavior are of prime importance to enable vector control. The intensive research and destroy of mosquito breeding habitats might be strongly supported by intersectoral collaboration. The inter-agency dengue task force, public and private institutions and the community itself have been orchestrated to combat the increasing dengue trend. Our results lead to the conclusion that an early warning system comprising both the control and prevention of *A. albopictus* is essential in lowering disease incidence and burden on healthcare and economic systems timely.

Keywords

Dengue Fever Management, Vector Control, Mosquito Control, *Aedes albopictus*

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1. Introduction

Probably, dengue is spread everywhere by Aedes mosquitoes (Diptera: Culicidae) including *Aedes aegypti* (Linnaeus) and *Aedes albopictus* (Skuse). Dengue and *A. aegypti* existed in Asia for centuries without serious consequences, and the distribution of *A. aegypti* has been limited to a little extent by *A. albopictus*, which is an indigenous Asian mosquito and is physiologically capable of transmitting dengue. Asian towns and cities are well endowed with trees and shrubs, and *A. albopictus* competitively to some extent excluded *A. aegypti* wherever there are vegetations. Originally, *A. albopictus* is a tree-hole-breeding mosquito and it acquired long ago an urban life style by breeding in similar situations around human habitations. Mosquito *A. albopictus* now also breeds in man-made containers such as water storage tanks, wells and discarded objects that collect rainwater. The mosquito lays its eggs on the side of a container a few millimeters above the water level. The eggs can sit for months without hatching if these remain dry, but hatch within minutes if

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covered with water for the larvae to complete their development before the container dries out (Marten, 1990; Sarwar, 2014 a; 2014 b; Sarwar, 2015 a; Sarwar, 2015 b).

Dengue fever also referred to as the break bone disease associated with the symptoms of muscle and joint pain, is a mosquito-borne viral infectious disease. The symptoms of dengue disease include sudden onset of fever, severe headache, muscle ache, joints pain, rashes, leucopenia, and thrombocytopenia. The dengue disease is usually self-limiting and the patients typically recover within a week. A small percentage of dengue patients could develop fatal complications or severe dengue characterized by severe organs impairment, plasma leakage, and dengue hemorrhagic fever which could lead to dengue shock syndrome. The dengue hemorrhagic fever is characterized by general symptoms of dengue fever plus symptoms that include skin hemorrhages, bleeding nose or gum and possible internal bleeding. Case fatality rates from severe dengue could be lower than 1% with appropriate case management and medical care by healthcare professionals. Dengue shock syndrome has all of criteria of dengue hemorrhagic fever plus circulatory failure as evidenced by rapid and weak pulse and narrow pulse pressure (< 20 mm Hg) or age-specific hypotension and cold clammy skin and restlessness (Singhi et al., 2007; Halstead, 2007).

2. Laboratory Criteria for Dengue Diagnosis

Laboratory criteria to diagnose dengue infection is with a blood test to check for the virus or antibodies in it to be checked for complications inclucing isolation of dengue virus from or demonstration of specific arboviral antigen or genomic sequences in tissue, blood, cerebrospinal fluid, or other body fluid by polymerase chain reaction test, immunofluorescence or immunohistochemistry; or seroconversion from negative for dengue virus-specific serum Immunoglobulin M (IgM) antibody in an acute phase (≤ 5 days after symptom onset) specimen positive for dengue-specific serum IgM antibodies in a convalescent-phase specimen collected ≥ 5 days after symptom onset; or demonstration of a ≥ 4-fold rise in reciprocal Immunoglobulin G (IgG) antibody titer or Hemagglutination inhibition titer to dengue virus antigens in paired acute and convalescent serum samples; or demonstration of a ≥ 4-fold rise in plaque reduction neutralization test end point titer (as expressed by the reciprocal of the last serum dilution showing a 90% reduction in plaque counts compared to the virus infected control) between dengue viruses and other flaviviruses tested in a convalescent serum sample; or virus-specific immunoglobulin M (IgM) antibodies demonstrated in cerebrospinal fluid (Kao et al., 2005; Bessoff et al., 2008).

3. Dengue Fever Transmission

Dengue fever is transmitted by the bite of an Aedes mosquitoes infected with a dengue virus. The mosquitoes become infected when it bites a person with dengue virus in the blood. The dengue viruses are transmitted via infective female mosquitoes, namely *A. aegypti* and *A. albopictus*, through bites or blood meals on human hosts. Mosquito *A. albopictus*, also called the Asian tiger mosquito, is a vector for a series of human arboviruses among which flaviviruses (dengue virus, yellow fever virus, Japanese encephalitis virus and West Nile virus) and togaviruses (Ross River virus and Chikungunya virus) are common (Mitchell, 1995; Gratz, 2004; Paupy et al., 2009). The species *A. albopictus* is known to be an important vector of dengue that can be second only to *A. aegypti*. The *A. albopictus* mosquito is a highly invasive mosquito species and has an excellent ability to colonize new environments. It is an aggressive day-biting mosquito whose bites can cause dermatological and allergic reactions. It can choose a habitat based on availability of food resources and availability of locations for reproduction and development. The species is capable of utilizing natural as well as artificial container habitats. It is considered a container breeder, preferring to oviposit in small quantities of water such as drums, tires, buckets, flower saucers, tarpaulins and manholes (Carrieri et al., 2003).

Dengue viruses can be transmitted by *A. albopictus*, and may cause acute febrile illness in humans, sometimes may be complicated by severe joint pains. However, *A. albopictus* has begun a dramatic geographic expansion that continues to the present day. It is a generalist that readily adapts to diverse environmental conditions in both tropical and temperate regions (Rai, 1991). The *A. albopictus* is a day-biting species that belongs to the subgenus Stegomyia and has a single longitudinal silvery dorsal stripe and white banded legs. Morphologically males are slightly smaller than females in the species, with the exception in the antennae which are much bushier in the males. It mostly occupies an outdoor (garden) and bites, rests, and lays eggs in thickets and arboreal vegetations. The tires are attractive oviposition sites for this species of mosquito and larvae can develop in the tires after raining and small puddles are left in the tires. This has caused considerable concern among some scientists and public health officials over the possibility that range expansion by this species will increase the risk of arthropod-borne virus (arbovirus) transmission (Benedict et al., 2007).

The possibility of *A. albopictus* for changing the transmission dynamics of both introduced and indigenous arboviral diseases, and increasing the risk of human infection, has stimulated increased vectorial capacity research on this species in the past two decades. The *A. albopictus* appears to be susceptible to infection, and is able to transmit most viruses for which it has been experimentally tested, including eight alphaviruses, eight flaviviruses, and four bunyaviruses, representing the three main arbovirus genera that include human pathogens. In addition to chikungunya virus, the only other human pathogens known to be transmitted in epidemic form by *A. albopictus* are the four serotypes of dengue virus (DENV-1, 2, 3 and 4). The *A. albopictus* can acquire all four existing dengue virus serotypes by feeding on dengue-viraemic peoples. It can transmit these viruses by taking subsequent blood meals on other non-dengue infected peoples. Dengue is the most prevalent human arboviral infection worldwide and. *A. albopictus* is reportedly responsible for dengue epidemics during World War II. The dramatic global expansion of *A. albopictus* in the last three decades has increased public health concern because it is a potential vector of numerous arthropod-borne viruses including the most prevalent arboviral pathogen of humans, dengue virus. Also of concern is the fact that as well as the dengue viruses, *A. albopictus* is a competent vector under experimental conditions for at least 22 arboviruses, including the internationally important yellow fever virus (Hotta, 1998; Scholte et al., 2007).

The dengue virus has been detected in *A. albopictus* mosquito and male *A. albopictus* reared from field-collected larvae tested positive for DENV, suggesting vertical transmission of dengue. Vertical transmission may be an additional mechanism for the maintenance of DENV in nature. Males of the species can transmit it by mating and females can transmit it vertically more efficiently than A. aegypti can do (Vazeille et al., 2003). The feeding patterns of haematophagous arthropods are of major importance in the amplification and transmission of infectious disease agents to vertebrate hosts, including humans. The establishment of new vector populations in nonnative range might alter transmission networks. The *A. albopictus* represents an example of how an invasive species can alter the risk of viral transmission to humans. Blood meal molecular identification from two sympatric mosquito species carried out by polymerase chain reaction-based methods showed *A. albopictus* acquired blood exclusively from human hosts (100%). Based on mosquito diet, the results suggest that *A. albopictus* invasion might increase the risk of virus transmission to humans and could support local outbreaks of imported tropical viruses such as dengue (Joaquín et al., 2011). In addition to the menace of dengue transmission, there are other reasons why this potentially invasive mosquito species is not welcome, including nuisance, competitiveness with indigenous mosquito species and transmission of other disease agents. This mosquito species will likely continue to spread globally, regardless of efforts to prevent its range of expansion.

4. Dengue Control

Dengue infestation can be discouraged by taking simple precautions around premises and places of residence, in particular, paying special attention to areas that encourage water accumulation. The following guideline aims to give insight into the activities that can be performed to prevent and control the incidence of dengue disease and to effectively reduce the risk of other mosquito-borne disease in the population of a county like larval mosquito surveillance and control, adult mosquito surveillance and control and human disease surveillance.

4.1. Prevention of Mosquito

Obtaining as much as possible relevant information about the status of mosquito-borne diseases including the preventive medicine, occupational and community health, environmental science and vector research are essential. Also, obtaining copies of any operational plans, guidelines, literature and raw data on mosquito-borne diseases that may have been compiled are necessary. Education efforts can be made to raise awareness on prevention of mosquito-borne diseases. Ensuring of the community understanding on environmental controls that can help to reduce mosquito habitat might prove to be a more effective means of control than the repeated use of larvacide and adulticide. It is imperative that personnel should learn what diseases mosquitoes transmit, how to recognize mosquitoes and how to avoid them. A variety of agencies can be contacted to obtain information for the training of medical, pest management and other personnel working on dengue. Additional educational methods include making brochures, pamphlets and fact sheets for availability of personnel; publishing periodic notices or plan of the day in the newspapers, particularly during warm months and the fall hunting season. Personal protective measures such as proper clothing can limit access of mosquitoes to the skin, thereby helping to prevent their bites. Pant should be bloused or tucked into the boots or socks, and the shirt should be tucked into the pant. If the shirt cannot be tucked, the next best thing is to wear an undershirt that is tucked into the pant to serve as a second layer for mosquito defense. Additional precaution to take is checking of window and door screens that should be mosquito tight and their repairing or replacing if needed or keeping windows and doors shut from the evening to dawn where residence do not have screens.

Interestingly, a need exists to further develop new technologies, such as remote sensing and geographic information systems analysis, for estimating mosquito vectors abundance in a habitat and predicting adult vector population outbreaks. Remote sensing technology is obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object area under investigation. Traditional methods of acquiring remote sensing data employ cameras or a variety of electronic sensing devices that can be mounted on platforms located anywhere from a few meters to thousands of kilometers from the object or area of interest to predict both the spatial and temporal dynamics of vector populations and disease transmission risk (Lillesand and Kiefer, 1987). Using smart cell phones supports the use of field capture and rapid transfer of mosquito vector surveillance data to a central database. The cell phones exploit existing communication infrastructure, introduce near real-time monitoring and provide rapid feedback to field data collectors. It also eliminates phone-based application for the collection of data on mosquito vectors of dengue virus (Akash and Ahmed, 2013). The application of an early warning system is essential in both the control and prevention of a disease outbreak in that it allows individuals and institutions to take timely action in high risk areas. A timely and effective response to an early warning could lower disease incidence rates and burden on healthcare and economic systems stemmed from epidemics. An early warning system should check awareness and knowledge of the threat, surveillance and forecast, comprehensible communication, and timely response (Lee et al., 2010). Continual research on innovative ideas and tools for dengue surveillance and control can help to improve the effectiveness and efficiency of vector control.

4.2. Control of Mosquito

The most frequent type of vector control is mosquito control using a variety of strategies to protect the health and welfare of the communities. Vector surveillance and control is a major component of preventing the transmission of arboviruses for suppression of disease in public health. Although eradication of most insect pests in indoor environment is feasible, yet control of insect vectors in the outdoor surroundings is much more complicated and difficult. Moreover, control of *A. albopictus* is generally regarded as very difficult because the larval breeding sites are not easily located in an urban environment and control of adults by using chemical pesticides in densely populated areas faces many practical obstacles. Vector surveillance and control include regular surveillance and intensive source reduction operations to eliminate mosquito-breeding habitats. The vector surveillance includes analysis of Aedes density and breeding habitats based on geographical locations of thousands of ovitraps across the locality.

The best way to reduce mosquito population is to eliminate the places where mosquitoes breed because standing water provides the ideal breeding spot for mosquitoes. All mosquitoes require water to complete their life cycle, so, draining of watering troughs weekly, repairing of water leaks, removing of vegetation and floating debris in and around ponds and stagnant swimming pools to limit breeding potential, filling of stumpy spots and draining of standing water from buckets and other containers that can collect water, may be considered necessary. Removing or turnover of any container that can hold water, storing unused tires inside a garage or shed, clearing obstructions to promote flow of water in drains and filling of tree holes with sand or mud are some other ways to help in preventing of mosquitoes (Sarwar, 2014 c).

Ideally, maternally inherited rickettsial symbionts of the genus Wolbachia occur commonly in *A. albopictus* (naturally infected with two Wolbachia strains), often behaving as reproductive parasites by manipulating host reproduction to enhance the vertical transmission of infections. One manipulation is cytoplasmic incompatibility, which causes a significant reduction in brood hatch and promotes the spread of the maternally inherited Wolbachia infection into the host population. The researchers have introduced a third Wolbachia strain into this mosquito, which is expected to help in blocking dengue transmission (Sarwar, 2014 d). Some other biological approaches are also being considered as alternatives to control mosquito populations, for instance, predatory crustaceans called copepods and many varieties of fishes including mosquitofish and goldfish, and frog tadpoles eat mosquito larvae. When these organisms are placed in container habitats, decorative ponds and pools, these prey on mosquito larvae, thus effectively preventing mosquito development (Dieng et al., 2002; Willems et al., 2005; Mokany, 2007; Rozilawati et al., 2007; Weeraratne et al., 2013).

Treating water with larvicide and adulticide pesticides are the available options for control of mosquito populations. Larvicide chemical *Bacillus thuringiensis* targets mosquitoes during their larvae stage and insect growth regulator Methoprene prevents larval mosquitoes from emerging as adult mosquitoes due to death at the pupal stage. Adulticides chemicals are applied to vegetation and around homes to reduce adult mosquito populations. Barrier sprays pyrethrins, deltamethrin, cyfluthrin, malathion, bifenthrin can be applied to shaded areas where mosquitoes rest. Fogging by permethrin and resmethrin should be applied at dusk and dawn which are active times for mosquito activity. Legislation measures, such as the control of vector, and pesticides acts and the environmental public health acts, are very helpful to enable vector control. For protecting public health by minimizing exposure to disease transmitting mosquitoes, and conducting research aiming to minimize mosquito nuisance and mosquito-borne disease risk at local and state levels are incredibly supportive.

5. Conclusion

Currently, because there is no effective vaccine against dengue and no specific treatment for the dengue disease, so, controlling and preventing of mosquito vector's outbreak are essential steps for keeping peoples healthy. Until in the absence of an effective and multiple actions vaccine that protects humans from dengue, limiting contact between peoples and vectors is the most effective way to prevent dengue infections. Environmental management of dengue mosquito populations, personal actions to reduce contact with mosquitoes, traps and bioinsecticides are effective in killing the mosquito larvae and reducing the number of adult mosquitoes to protect against dengue. New biological, genetic and chemical approaches are also being developed and these may provide promising alternatives to control mosquito populations, and prevent dengue infections among peoples. Finally, the integrated mosquito management methods are comprehensive and specifically modified to safely counter each stage of the mosquito life cycle. Larval control through water management and source reduction, where compatible with other land management uses, is a sensible vector management strategy. When vector's source elimination or larval control measures are clearly inadequate or in the case of eminent disease outbreak, it should be important to consider for application of adulticides. A successful mosquito management program should include the elements of larval and adult mosquito samplings, source reduction, biological control using native or introduced predators and parasites of mosquitoes, larviciding and adulticiding when indicated by surveillance, resistance monitoring, disease surveillance in mosquitoes and public education. In the final analysis, houses and premise sanitation is the key to control *A. albopictus* mosquito problem.

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