Review Article

*Aedes vittatus* (Bigot) mosquito: An emerging threat to public health

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**ABSTRACT**

*Aedes vittatus* (Bigot) mosquito is a voracious biter of humans and has a geographical distribution throughout tropical Asia, Africa and the Mediterranean region of Europe. It is predominantly a rock-hole breeder, though it can breed in diverse macro- and micro-habitats. The mosquito plays an important role in the maintenance and transmission of yellow fever (YFV), dengue (DENV), chikungunya (CHIKV) and Zika (ZIKV) viruses. It has been implicated as an important vector of YFV in several African countries as evidenced by repeated virus isolations from the mosquito and its potential to transmit the virus experimentally. Similarly, DENV-2 has been isolated from wild caught *Ae. vittatus* mosquitoes in Senegal, Africa which has been shown to circulate the virus in sylvatic populations without causing human infection. Experimental studies have shown replication of the virus at a low scale in naturally infected mosquitoes while high rate of infection and dissemination have been reported in parenterally infected mosquitoes. Natural isolation of ZIKV has been reported from Senegal and Cote d’Ivoire from these mosquitoes. They were found highly competent to transmit the virus experimentally and the transmission rate is at par with *Ae. leuteocephalus*, the primary vector of ZIKV. A few CHIKV isolations have also been reported from the mosquitoes in Senegal and other countries in Africa. Experimental studies have demonstrated high susceptibility, early dissemination and efficient transmission of CHIKV by *Ae. vittatus* mosquitoes. The mosquitoes with their high susceptibility and competence to transmit important viruses, viz. YFV, DENV, CHIKV and ZIKV pose a major threat to public health due to their abundance and anthropophilic behaviour.

**Key words**  
*Aedes vittatus*; chikungunya; dengue; Zika; yellow fever

**INTRODUCTION**

*Aedes vittatus* (Bigot) mosquito, initially identified as *Culex vittatus*, first reported from Corsica in Europe, has garnered public attention recently due to its association with Zika virus (ZIKV)\(^1\)–\(^2\). In addition, the mosquito is known to play an important role in the maintenance and transmission of viruses of public health importance, viz. yellow fever virus (YFV), dengue virus (DENV), and chikungunya virus (CHIKV). All the viruses have been repeatedly isolated from wild caught mosquitoes demonstrating their role in the maintenance of these viruses in nature\(^1\). Experimental studies have also shown their potential not only in replicating these viruses but also in transmitting them to susceptible hosts. Initially the mosquito was placed under subgenus *Stegomyia* due to morphological similarities; but, subsequently placed under subgenus *Aedimorphus* and later on under the subgenus *Fredwardsius* based on the distinctive characteristics that distinguished it from other subgenera of genus *Aedes*\(^2\)–\(^3\). It is a peridomestic mosquito and found breeding in various microhabitats, but predominantly in rock pools\(^4\). Three pairs of small round silvery white spots on the scutum makes the mosquito easily distinguishable from other commonly found *Aedes* species. Other characteristic features include, wings with narrow scales on all veins, dark tibiae with white spots, presence of white band on the base of tibiae, white bands on the tarsomeres 1–4, fully white fifth tarsomere \(^4\). The expansion of geographic distribution, ability to breed in various macro- and micro-habitats, high anthropophily (readily feeds on humans) and competence to transmit important arboviruses makes it an important mosquito species to be dealt with. This review, discusses the geographical distribution of *Ae. vittatus* mosquito, its breeding habitats, susceptibility to arboviruses of public health importance and potential to act as an important vector or abridge vector of viruses like YFV, CHIKV, DENV and ZIKV.

**Global distribution**

The *Ae. vittatus* mosquito is geographically distributed throughout tropical Asia, Africa and the Medi-
terranean region of Europe. It is predominantly found throughout Africa either as a canopy (sylvatic) mosquito, forest ground mosquito or peridomestic mosquito in rural areas. In Europe, the species is restricted to the occidental Mediterranean region comprising Italy, France, Spain and Portugal. In Asia, the mosquito is found in several countries including India. The countries in the three continents where the mosquito is highly prevalent are listed in Table 1. The Fig. 1 depicts the global distribution.

**Breeding habitats**

*Aedes vittatus* is predominantly a rock-hole breeder in Africa, though it can breed in diverse macro- and micro-habitats. Species distribution study in rock pools on inselbergs in northern Nigeria has shown predominant breeding of *Ae. vittatus* mosquitoes, contributing to 92.8% of the total population. The investigators also observed that the species is least affected by physico-chemical parameters of the rock hole habitats. Another study has also reported the high prevalence of the mosquito in Katsina area of Nigeria where breeding was mainly observed in rock pools. On the contrary, Diallo et al. observed maximum breeding of the mosquito in puddles (52.3%) followed by rock holes (48.3%), discarded containers (2.9%), tree holes (0.7%) and fresh fruit husks (0.5%) in Kedougou region in Senegal. They also observed that though the mosquito was prevalent in forest, savannah, barren land, and village land covers, the maximum prevalence was observed in the savannah and barren land covers. Studies on the seasonal prevalence of the mosquitoes have shown their presence mainly during June to October in the forested land cover; June to August in savannahs, July to October in barren lands and June to October in village land covers. However, in the Osogo metropolis in southwestern Nigeria, breeding of the mosquito was mainly found in discarded containers and septic tanks. Similar to these results, Tewari et al. reported profuse breeding of the mosquitoes throughout the year in peridomestic/outdoor containers in India. The breeding was observed in cement tanks, cement cisterns, mud pots, metal and

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<th>Continents</th>
<th>Countries</th>
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<tr>
<td>Asia</td>
<td>Bangladesh, China, Cambodia, India, Iran, Laos, Malaysia, Nepal, Pakistan, Saudi Arabia, Sri Lanka, Thailand, Vietnam and Yemen</td>
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<tr>
<td>Europe</td>
<td>France, Italy, Portugal and Spain</td>
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![Data not available](image)

*Fig. 1: Geographic distribution (Grey area) of *Ae. vittatus* mosquitoes.*
plastic containers and discarded containers with almost equal proportions in three dengue endemic villages in Vellore district, Tamil Nadu. However, cement tanks and cement cisterns showed higher breeding preference in comparison to other containers. Rajavel et al.\textsuperscript{12} reported the presence of this mosquito in the mangrove forests of Karnataka and Kerala. They observed the prevalence of the immatures mainly in tree holes and swamp pools. The mosquito eggs are highly resistant to extreme temperature and other climatic conditions and can tide over the dry season for prolonged periods\textsuperscript{13}, as the researchers observed the emergence of \textit{Ae. vittatus} larvae from eggs that were lying in granite rock pools at the temperature of 40°C and relative humidity of 5% for 4.5 months.

**Public health importance of \textit{Ae. vittatus}**

\textit{Aedes vittatus} is a voracious biter of humans and plays an important role in the maintenance and transmission of several arboviruses. It has been incriminated as an important vector of yellow fever in Africa as evidenced by virus isolations and its high anthropophily\textsuperscript{8}. Several other viruses, viz. dengue, chikungunya and Zika have been isolated from the mosquito demonstrating its potential to replicate and transmit these viruses experimentally. However, its role as a vector of these viruses still needs further investigation.

**Natural isolations and experimental studies with arboviruses of public health importance**

\textit{Yellow fever virus:} Yellow fever is highly endemic in sub-Saharan Africa and tropical South America with approx. 2,00,000 cases and ≥30,000 deaths annually, despite having an effective vaccine\textsuperscript{14}. The virus is transmitted by a plethora of mosquito species comprising sylvatic, rural and urban mosquitoes\textsuperscript{15}. Several isolations of the virus have been made from \textit{Ae. vittatus} mosquitoes in Nigeria, Senegal, Cote d’Ivoire, Sudan, West Africa etc. and the mosquito is being suspected as the natural vector of YFV\textsuperscript{8, 15}. During the YFV outbreak in Gambia 1978–79, it was suspected that \textit{Ae. vittatus} played an important role in the initial transmission\textsuperscript{16}. Experimental transmission of YFV to monkeys by infected mosquitoes has been shown successfully demonstrating the vectorial capacity of the mosquito\textsuperscript{17}.

\textit{Dengue virus:} Dengue is one of the most important arboviral infections of humans with approx. 390 million cases and over one million deaths annually\textsuperscript{18}. Several countries in Africa and Asia especially in the tropical and subtropical regions are endemic to the virus and is transmitted mainly by \textit{Ae. aegypti} and \textit{Ae. albopictus} mosquitoes. \textit{Aedes vittatus} has also been indicted as a probable vector of DENV as evidenced by virus isolations and their ability to replicate and transmit the virus in the laboratory. Diallo et al.\textsuperscript{19} reported the isolation of DENV-2 from wild caught female \textit{Ae. vittatus} mosquitoes (sylvatic populations) from southeastern Senegal during 1999–2000. Isolation of DENV-2 from sylvatic \textit{Ae. vittatus} mosquitoes without human infections has been reported from Cote d’Ivoire demonstrating sylvatic DENV circulation\textsuperscript{20–21}.

Experimental studies have shown that \textit{Ae. vittatus} mosquitoes are susceptible to infection with all four serotypes of dengue virus\textsuperscript{22}. Mavale et al.\textsuperscript{23} found that the infection rate is slow in oral fed mosquitoes (<5%) and presence of virus in brain tissues and salivary glands was detected only after Day 7 post-infection (PI) irrespective of serotypes. However, rapid increase in viral titre was observed in parenterally infected mosquitoes (>63%) as the virus could be detected on Day 5 PI for DENV-1, 2, and 3 serotypes and Day 7 PI for DENV-4. Maximum titre was detected on Day 9 PI (2.4 dex), and the mosquitoes maintained the titres in the range of 1.8 to 2.2 dex on subsequent days (between Day 11 and 15) PI. The investigators also demonstrated that despite having a low infection rate, salivary glands were found infected, indicating their competence to transmit the virus to susceptible hosts. Based on the results of the study, the investigators have opined that the mosquitoes, though with low infection rate, may act as a natural vector or play an important role in the maintenance of the virus in nature. Complementary findings were reported by Diallo et al.\textsuperscript{23} during their studies with DENV-2 in Kedougou, Senegal. They observed that \textit{Ae. vittatus} mosquitoes are less susceptible to DENV-2 (infection rate 6–18%), though they have shown higher rate of dissemination than highly susceptible vector mosquitoes, viz. \textit{Ae. furcifer} and \textit{Ae. luteocephalus}. The high dissemination rate is suggestive of their enhanced potential to transmit DENV-2. The authors, however, feel that the mosquito has little or no role in the transmission of dengue virus as evidenced by low susceptibility and the lack of infection in mosquitoes collected from epidemic areas along with \textit{Ae. aegypti} and \textit{Ae. albopictus}. Similar observation has been reported by Tewari et al.\textsuperscript{11} as they could not detect/isolate DENV from \textit{Ae. vittatus} mosquitoes collected from dengue endemic villages in Tamil Nadu, India.

\textit{Zika virus:} ZIKV has drawn global attention as an emerging and re-emerging pathogen of public health importance, with its potential to cause Guillian-Barré syndrome (GBS) and microcephaly in neonates in French
Polynesia and Brazil, respectively. The virus is transmitted mainly by *Ae. aegypti* mosquitoes, though several other *Aedes* mosquitoes including *Ae. vittatus* play an important role in the virus transmission. Three isolations of ZIKV have been reported from *Ae. vittatus* adult mosquitoes collected from the Kedougou region in Senegal of western Africa during June–September 2011. ZIKV positivity was observed in mosquitoes collected from forest canopy, forest ground and villages. Isolation of ZIKV has also been reported from Cote d’Ivoire from *Ae. vit- tatus* during an investigation of YFV outbreak in 1999.

In a study, experimentally infected *Ae. vittatus* (Kedougou strain) mosquitoes not only replicated ZIKV, but also showed high dissemination rate (27%) to different organs of the mosquito. The investigators of the study also detected presence of the virus in saliva in a small proportion, demonstrating its competence to transmit the virus. Transmission rate was found at par with *Ae. luteocepha- lus*, the primary vector of ZIKV in Senegal. However, the low infection rate of salivary glands of the former is a question mark on its potential to transmit the virus. The *Ae. aegypti* strains from Kedougou and Dakkar also replicated ZIKV, but failed to transmit the virus.

**Chikungunya virus:** CHIKV was first isolated in Tanzania in 1952–53 during an outbreak of dengue like illness, which subsequently spread to other African and Asian countries causing outbreaks. During 2004, re-emergence of the virus in a virulent form was reported from the eastern coast of Africa which caused devastating outbreaks in Indian Ocean Islands, India and southeast Asia. Dramatic geographical expansion of the virus has been observed since 2012, leading to autochthonous transmission in the Caribbean Islands, South and North American countries. Though *Ae. aegypti* is incriminated as the principal vector of the virus, *Ae. albopictus* and several other mosquitoes play an important role in virus transmission. CHIKV has been isolated from *Ae. vittatus* mosquitoes on several occasions in Africa. Diallo *et al.* reported isolation of four strains of CHIKV during virological investigations in mosquitoes carried out in Kedougou, Senegal between 1972 and 1996.

Mourya and Banerjee demonstrated experimental transmission of CHIKV (Asian strain) by *Ae. vittatus* mosquitoes to infant mice on Day 5 post-infection (PI). Progressive increase in salivary gland positivity and transmission efficacy was observed as days of PI progressed, resulting in the highest percentage on Day 13 PI. The investigators, however, failed to demonstrate transovarial transmission of CHIKV by *Ae. vittatus* mosquitoes. Recently, Diagne *et al.* demonstrated high susceptibility, early dissemination and efficient transmission of West African strain of CHIKV by *Ae. vittatus* mosquitoes. The mosquitoes showed high infection rate ranging from 50 to 100% between Day 5 and 15 PI. The Kedougou strain of *Ae. vittatus* was found more competent to disseminate the virus than *Ae. aegypti* mosquitoes used in the study. It was also observed that the Kedougou strain of *Ae. vittatus* was having higher infection rate and virus dissemination than that of the Indian strains used by Mourya and Banerjee. Initial studies by Sudeep *et al.* (Unpublished data) have shown rapid replication of East/Central/South African (ECSA) strain of CHIKV in an Indian strain of *Ae. vittatus* mosquitoes. The investigators observed a log increase in virus titre on Day 3 PI in intra-thoracically inoculated mosquitoes. The mosquitoes maintained the titre without significant changes throughout the study period of 12 days. Virus dissemination to legs and wings was also found at a higher rate as virus could be detected in these organs on Day 3 PI with titres of 4 and 0.7 log TCID50/ml, respectively. Virus dissemination to salivary glands and saliva was detected only on Day 6 PI (1.23 log TCID50/ml) but increased to ~4 log TCID50/ml on Day 12 PI. However, they could not demonstrate virus replication in orally fed mosquitoes.

**Susceptibility and transmission potential to other arbovirus of public health importance**

Though, *Ae. vittatus* is not implicated as a vector for any other arboviruses apart from those mentioned above, recent studies by Sudeep *et al.* (Unpublished data), have revealed the susceptibility of the mosquito to several viruses of public health importance in India. Japanese encephali- tis (JEV), West Nile (WNV) and Chandipura viruses were found replicating in the mosquito when infected by intra-thoracic inoculation. The mosquitoes maintained JEV for a period of 12 days, but the salivary glands were not found infected. On the contrary, high degree of WNV replication was found in the mosquitoes with rapid dissemination to wings, legs and salivary glands as early as on Day 6 PI. WNV was detected in saliva with a titre of >3 log TCID50/ml on Day 6 PI with a progressive increase on subsequent days PI (up to Day 12 PI) demonstrating its vector potential.

**Recommendations**

Not much importance has been given to the mosquito as a vector to-date, despite the isolation of important arboviruses, *viz.* dengue, chikungunya, yellow fever and Zika viruses. Vector competence to WNV is an important finding and will have major repercussions if the mosquitoes are exposed to the virus. More studies are needed to
determine the potential of the mosquito and to confirm its vectorial capacity.

CONCLUSION

The last few decades have seen the emergence and re-emergence of several arboviruses in virulent forms causing severe outbreaks across the globe. The re-emergence of chikungunya virus and recently the Zika virus have garnered global attention due to high disease burden and loss of human lives. The population explosion of mosquitoes and other arthropods due to global warming, increased commerce and travel as well as man-made changes to the environment has contributed to increase in arthropod-borne infections globally. The population of mosquitoes, mainly *Ae. aegypti* and *Ae. albopictus*, has shown tremendous global expansion and play an important role in the transmission of major arbovirus infections, viz. dengue, chikungunya, yellow fever and Zika virus diseases. *Aedes vittatus*, another important member of the genus has wide distribution in Asia, Africa and the Mediterranean countries and plays an important role in the maintenance and transmission of the above viruses. All the four important arboviruses, viz. dengue, chikungunya, yellow fever and Zika viruses have been isolated from *Ae. vittatus* mosquitoes with experimental evidence of transmission. The mosquito may be playing a low key role by maintaining these viruses during non-epidemic periods. However, its high susceptibility to these important viruses, high rate of dissemination; and high anthropophily make these mosquitoes a concern for public health should there be any adaptation by viruses as observed for *Ae. albopictus* mosquitoes during the chikungunya outbreak in La Reunion and India during 2005–06.

Conflict of interest: None.

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