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The first report of a mosquito species *Aedes infirmatus* (Diptera: Culicidae) from the state of Rajasthan in India

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Abstract
Aedes infirmatus is also known as the infirm American pointy mosquito or silverback mosquito. This mosquito is a competent vector for Eastern Equine encephalitis virus (EEEV) and is also associated with the transmission of keystone virus (KEYV), Tensaw virus (TENV), Trivittatus virus (TVTV), and West Nile virus (WNV). This species usually occurs in Honduras, Mexico, and the Southern United States. The larvae were collected during a routine entomological survey from July to October 2022 from Bassi of the Begun block in Chittorgarh district, Rajasthan, India (Latitude 25.030421° N & Longitude 74.80191° E). Adults were morphologically identified using taxonomic keys and online research literature. Based on morphological characteristics, the mosquito specimen has been confirmed as *Aedes infirmatus* Dyar and Knab (1906). High rainfall (average annual 848 mm), moderate temperature (11.6ºC-44ºC), and high plantation with a hill range and water sources i.e., Bassi pond, Orai dam, and Bassi dam in the area provide breeding sites and may favour the invasion and establishment of this species. The presence of *Aedes infirmatus* in Chittorgarh, Rajasthan may have been a significant indication of the invasion in another part of India.

Keywords: *Aedes infirmatus*, Culicidae, India, Mosquito, Rajasthan

Introduction
Aedes infirmatus, also known as the infirm American pointy mosquito or silverback mosquito. These are aggressive biters, nuisance pests, and floodwater mosquitoes [1]. They belong to the *Ochlerotatus* Group which includes 24 species and are distributed throughout the tropical and temperate Americas [2, 3]. *Aedes infirmatus* is a competent vector of arboviruses i.e., Eastern Equine encephalitis virus (EEEV) which causes a rare but severe disease in horses and Eastern Equine Encephalitis in humans [1, 4, 5]. This mosquito is also a vector for the keystone virus (KEYV) and appears to play a lesser but still important role in the transmission of this virus [6]. Transmission of some other viruses such as Tensaw virus (TENV), Trivittatus virus (TVTV), and West Nile virus (WNV) is also associated with this species [7].
The distribution of this mosquito is limited to woodland environments in Honduras, Mexico, and the Southern United States [7]. Three species of the genus *Aedes* i.e., *Aedes aegypti*, *Aedes albopictus*, and *Aedes vittatus* are abundant in Rajasthan. During the routine surveillance activity in southern Rajasthan, an unexpected mosquito that did not belong to the recorded Indian mosquito fauna was collected. It is, to the best of our knowledge from available information, this case report describes the first known detection of *Aedes infirmatus* in India. The first report of the species in India from the state of Rajasthan has become a concern for public health and the invasion of this species in India.

Mosquito findings and identification
From July to October 2022, during a routine entomological survey in the southern part of Rajasthan, *Aedes infirmatus* larvae were collected with *Aedes aegypti* and *Aedes albopictus* larvae. The sample was collected from different locations in Bassi. Bassi is located in the Begun block in Chittorgarh district (Latitude 25.030421° N & Longitude 74.80191° E) of Rajasthan state (Figure 1) in a part of insecticide resistance monitoring. Larval collections were performed using a larval kit. Collected larvae were then transported to the laboratory to develop in adults under laboratory conditions (27±2ºC temperature and 75±10% relative humidity). A cotton-soaked 10% sugar solution in water was provided as food for adults. A total of 9 larvae were further developed in adults. Among them, 2 were confirmed as male and the remaining 7 were female. Unfortunately, the males lived very short and died before the hatching of females.
The specimen was morphologically identified as *Aedes infirmatus* Dyar and Knab (1906) using a taxonomic key and research literature [3, 8, 9, 10]. The identification and photography were done under the stereo zoom binoculars microscope (LEICA S9i and Leica EZ4 W) and processed in CorelDRAW 2021 software. The map to show the survey and sampling site is constructed using QGIS 3.22.10, Google Earth Pro, and CorelDRAW 2021 software.

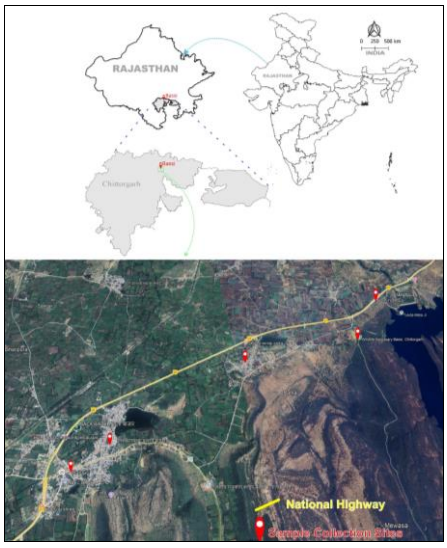

Fig 1: Map showing the locality of the first *Aedes Infirmatus* finding in India from the state of Rajasthan

Morphological characterization

The adults are black-brown with white bands or patches on the legs and abdomen in general appearance (Figure 2).

Head: The occiput is covered with white scales on the dorsal surface with erect scales. Maxillary palp is shorter than the proboscis and completely dark without white scales and the clypeus is dark without white scales. The proboscis is also dark throughout without white scales (Figure 3).

Thorax: Scutum has an anteromedian patch of white scales that extend to the middle of the thorax and are broader than the lateral dark-scaled areas (Figure 4). Post-spiracular setae are present on the lateral side of the thorax (Figure 5). Three white-scaled patches are present, one on mesepimeron and two on mesokatepisternum (upper and lower side) on the lateral side of the thorax. The supraalar area of the thorax has a pale scale patch upwardly extended toward the scutellum (Figure 5). Legs have a white patch at the basal part of the femur. The tibia of the hindleg is completely dark from base to apex without any white patch (Figure 6). Tarsomeres are without pale bands however, on the hindleg, 1st and 2nd tarsi have pale bands on the base and apex while only 1st tarsi of the midleg have pale bands on the base and apex (Figure 6). Wings are clear with narrow black scales (Figure 7)

Fig 2: *Aedes infirmatus* (male and female)

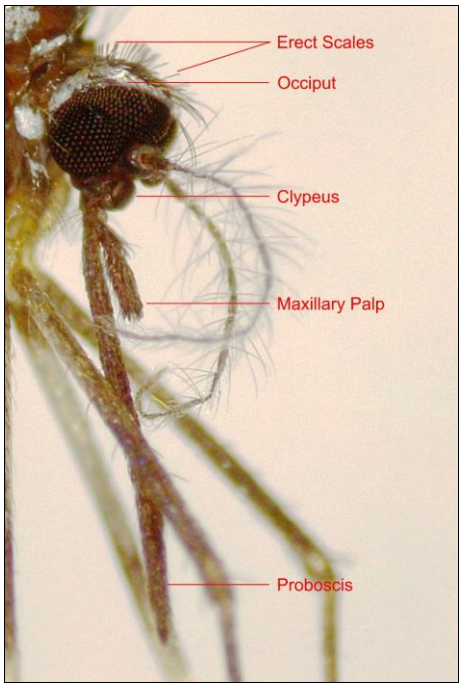

Fig 3: Head of *Aedes Infirmatus* characterizing occiput, clypeus maxillary palp and proboscis

Fig 4: Scutum having white scaled broad patch

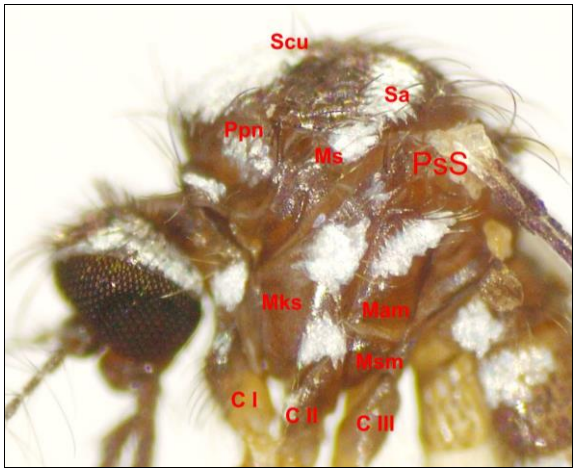

Fig 5: C I-forecoxa; C II-midcoxa; C III- hindcoxa; Mam mesepimeron; Mks- mesokatepisternum; MS-mesothoracic spiracle; Msm-mesomeron; Ppn-postpronotum; Scu- scutum; PsS-prespiracular setae; Sa-Supraalar area

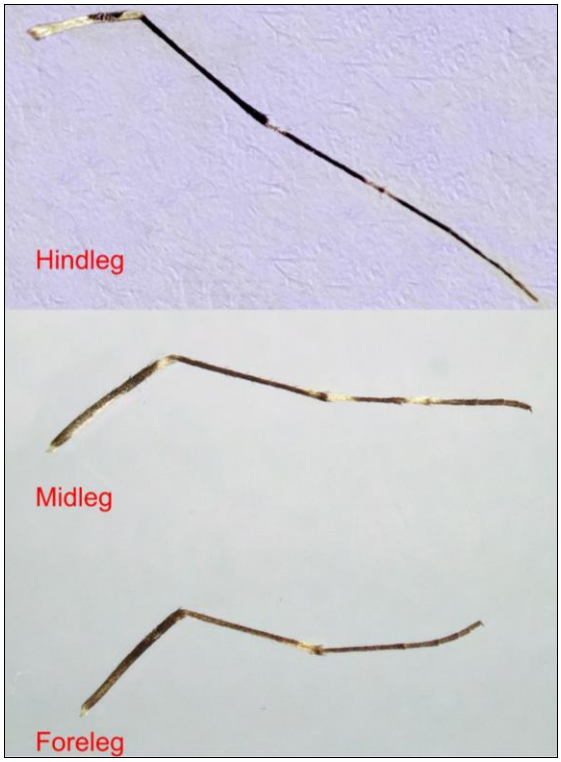

Fig 6: Legs showing banding pattern of white and black patches

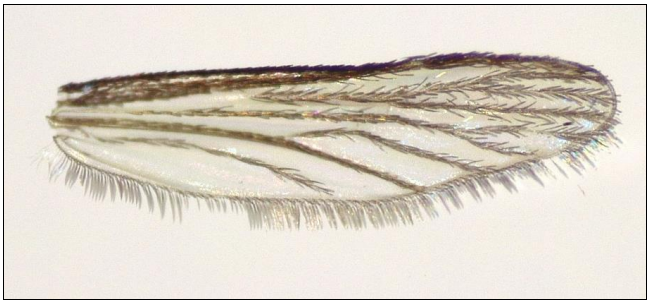

Fig 7: Wing having clear appearance with dark scales on veins

Abdomen: The abdomen is dark-scaled with basal triangular patches of pale scales on each segment of the abdomen. VI-VIII abdominal terga are darkly scaled medially. Sterna has a transverse pale band of white scales on each abdominal segment (Figure 8).

Fig 8: Abdomen showing white scaled pattern on dorsal, lateral and ventral side

Discussion and conclusion

Morphological features of adult females i.e., a broad white patch on scutum and band pattern of legs confirm the species *Aedes infirmatus* Dyar and Knab (1906). The completely dark tibia from base to apex distinguishes it from *Aedes scapularis* which is similar to this species probably due to being situated in the same group the "*Ochlerotatus"* [2, 3]. This species is originally found in Honduras, Mexico, and the United States [7]. This mosquito species was reported for the first time in the country and there is no earlier record of this species in India [7, 9, 11]. The first appearance of this species in the Bassi of Chittorgarh district is surprisingly unexpected as it is not a native species of India.

In October 2022, another mosquito species "*Psorophora columbiae*" was also reported for the first time in Banswara district of Rajasthan [12]. *Psorophora columbiae* is also distributed in the Bahamas, Belize, Canada, Cayman Islands, Cuba, Honduras, Mexico, Panama, and the United States where the *Aedes infirmatus* is also found [7,12]. In another study in the area of Auroville, Tamil Nadu, 8 new species belonging to *Anopheles* and *Culex* were also reported for the first time in India [13]. Studies suggest that the world became more suitable from 1.5% per decade during 1950–2000 which is predicted to accelerate to 3.2–4.4% per decade by 2050 for the development of *Aedes aegypti* [14]. In recent years, many mosquito species i.e., *Anopheles stephensi* and *Aedes albopictus* are also reported from new areas for the first time [15, 16].

Recent studies also claim the shifting of niche for *Aedes albopictus* from its native state during the invasion of North and South America and Europe [17]. The development and invasion of these species are favoured by global climatic conditions and can be a cause behind the invasion of *Aedes infirmatus* as they belong to the same genera. The invasion of this species may also be associated with climate change activities. The temperature ranges from 11.6ºC-44ºC with an average of 22.0±5ºC [18]. In 2022, the average annual rainfall was 848 mm in this district and the maximum was 1368.7 mm in Begun block from where the species was recorded [19]. The plantation is high with a hill range and water sources i.e., Bassi pond, Orai dam, and Bassi dam in this area from where the sample was collected that can provide breeding sites. Such climatic factors of the Chittorgarh district also favour the invasion and establishment of this species. The presence of *Aedes infirmatus* in Chittorgarh, Rajasthan may have been a significant indication of the invasion in another part of India. Further research is necessary to determine the interaction between invasion of new species and climate change activities. This diversity of mosquitoes should also be monitored over time.

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Declarations

Ethics approval: The script does not require ethical approval.
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Consent for publication: Not applicable.
Conflicts of interest: The author(s) have no conflict of interest.

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