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Review Article

Rubber Plantations as Mosquito Breeding Ecosystems: A Global Review

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I N F O

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A B S T R A C T

Rubber plantations provide a unique type of mosquito breeding habitat in the form of rainwater-filled latex cups. Remains of highly nutritious latex in the cups promote bacterial growth and hence support the growth of mosquito larvae. Globally, there are approximately 12.8 million hectares of land under rubber cultivation. Each hectare of plantation provides 500 latex cups. Since 1956, the breeding of mosquitoes in latex cups has been reported in four Asian countries viz., Malaysia, India, Laos PDR, and Indonesia. The dominant species in these habitats was *Aedes albopictus*, the vector of Dengue, Chikungunya, and Zika. In Africa, two countries viz., Liberia and Ivory Coast reported mosquito breeding in latex cups. The mosquitoes include the vector species Ae. *aegypti, Ae. africanus*, *Anopheles gambiae*, *Culex quenquefasciatus*, and *Cx. tritaeniorhynchus*. However, there have not been similar studies in many of the major rubber-cultivating countries.

Keywords: Rubber, Plantations, Mosquito, Latex Cups, Vector

Introduction

Natural rubber is obtained from the latex of *Hevea brasiliensis,* a tree species belonging to the family Euphorbiaceae. As the name indicates, it is originally a South American species. Since Spain was the principal power in South America in the initial years of colonisation, rubber, and its products were the monopoly of that country. Realizing the commercial prospects of rubber and its products, the British decided to end this monopoly. In 1876, the British planter Henry Wickham collected 70000 seeds of *Hevea brasiliensis* from Brazil and literally smuggled them to England. Using these seeds about 2700 seedlings were raised in Kew Garden. In the same year and the next, these seedlings were dispatched to Sri Lanka, Malaysia, Singapore, and Indonesia. This was the beginning of rubber cultivation in South and South East Asia.[1]

Rubber Plantations in the World

According to the latest statistics from the United Nations Food and Agriculture Organization (FAOSTAT), approximately 12.8 million hectares of land are under rubber cultivation in the world, of which 87.72% is in Asia. The major rubber-cultivating countries are Indonesia, Thailand, Malaysia, China, Vietnam, India, Laos PDR, Myanmar, Philippines, Sri Lanka, Bangladesh, and Cambodia in Asia; Ivory Coast, Nigeria, Liberia, Democratic Republic of the Congo, Cameroon, Ghana, Gabon, Guinea, Central African Republic, and Congo in Africa; Brazil, Guatemala, Mexico, and Ecuador in South America, and the Dominican Republic in North America. The top ten countries in terms of area under rubber cultivation are Indonesia, Thailand, Malaysia, China, Vietnam, Ivory Coast, India, Nigeria, Myanmar, and Cambodia (Figure 1).[2]

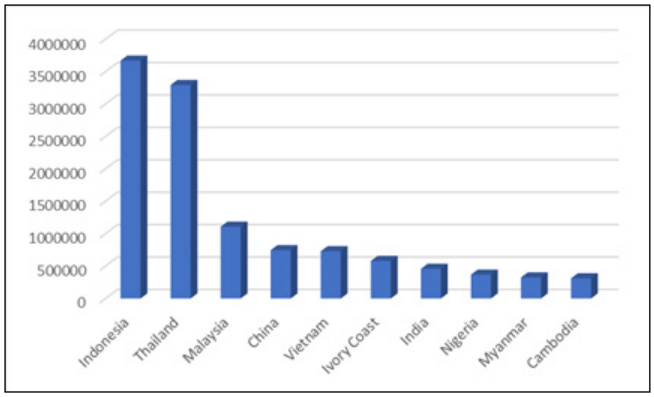

Figure 1.Top Ten Countries in Terms of Area (Hectares) Under Rubber Cultivation (Source: FAOSTAT 2023)

Breeding Habitats in the Rubber Plantations

Latex is extracted from the rubber trees by a process known as tapping. This is done by the controlled wounding of bark to cut open the latex vessels.[1] The latex thus flowing out is collected in coconut shells or plastic cups (hereafter called latex cups) attached to the trees using metallic wire hoops (Figure 2). During the rainy season, rainwater gets collected in these cups and serves as breeding habitats for mosquitoes.[3] Latex is a special type of cytoplasm, that contains rubber particles, carbohydrates, proteins, lipids, inorganic salts, and many other minor substances. Sucrose is the major carbohydrate.[4] The presence of the remains of this nutritious latex promotes bacterial growth, which in turn serves as food for mosquito larvae and makes these ideal habitats.[5] In one hectare of rubber plantation, there are approximately 500 trees, and hence 500 latex cups.[6]

Figure 2.Latex Cup Attached to the Rubber Tree

Mosquito Breeding in Latex Cups

Although the rubber-growing countries belong to four continents, mosquito breeding in latex cups has so far been reported only in Asian and African countries (Table 1).

Table 1.Mosquito Species Breeding Latex Cups in Rubber Plantations

S. No.	Mosquito Species	Country	Vector Status
1	*Aedes aegypti*	Liberia, Malaysia, Ivory Coast	Dengue, yellow fever, chikungunya, Zika
2	*Ae. africanus*	Liberia	Yellow fever
3	*Ae. albopictus*	India, Lao PDR, Malaysia	Dengue, yellow fever, chikungunya, Zika
4	*Ae. apicoargenteus*	Liberia	-
5	*Ae. chrysolineatus*	India	-
6	*Ae. cogilli*	India	-
7	*Ae. frazeri*	Liberia	-
8	*Ae. gubernatoris*	India	-
9	*Ae. harveyi*	India	-
10	*Ae. simpsoni*	Liberia	-
11	*Ae. subalbopictus*	India	-
12	*Anopheles gambiae*	Liberia	Malaria
13	*Armigeres subalbatus*	India, Malaysia	-
14	*Culex brevipalpis*	India	-
15	*Cx. decens*	Liberia	-
16	*Cx. horridus*	Liberia	-
17	*Cx. ingrami*	Liberia	-
18	*Cx. macfei*	Liberia	-
19	*Cx. nebulosus*	Liberia	-
20	*Cx. quenquesfaciatus*	Malaysia, Ivory coast	Lymphatic filariasis
21	*Cx. tritaeniorhynchus*	Liberia	Japanese Encephalitis
22	*Cx. uniformis*	India	-
23	*Eretmapodites chrysogaster*	Liberia	-
24	*Er. leucopus*	Liberia	-
25	*Er. oedipodius*	Liberia	-
26	*Heizmannia chandi*	India	-
27	*Lutzia tigripes*	Liberia	-
28	*Toxorhynchites splendens*	India, Indonesia	-
29	*Tx. brevipalpus*	Liberia	-
30	*Verrallina species*	India	-

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Asian Countries

Amongst the 10 leading countries in rubber cultivation, eight are in the Asian continent. However, only three of these countries viz, Malaysia, Indonesia, and India reported mosquito-breeding in latex cups. Besides these top countries, Laos DPR also reported the same.

Malaysia

The first global record of mosquito breeding in latex cups was from Malaya, which is in present-day Malaysia, in 1956.[7] During an extensive survey for the distribution of *Aedes aegypti* in Malaya, profuse breeding of *Aedes albopictus* was observed in latex cups filled with rainwater in the rubber plantations of coastal and inland areas. However, *Aedes aegypti* was not observed.

After 1956, there were no studies on the breeding status of mosquitoes in latex cups in this country till 2001. In 2001, while conducting a survey of mosquito larvae distribution in urban and rural Malaysia, the breeding of four species of mosquitoes, viz., *Aedes albopictus*, *Ae. aegypti, Armigeres subalbatus*, and *Culex quinquefasciatus* were observed in latex cups. Of the total breeding, 2.5% was in this type of habitat. While *Armigeres subalbatus* was the most abundant species, it was closely followed by *Aedes albopictus*. Breeding of the remaining two species was negligible.[8]

India

The pioneering study on the role of latex cups as mosquito breeding habitats was done in 2002. In June 2002, mosquito surveys were conducted in the rubber plantations of three villages each in the Wayanad and Kannur districts of North Kerala following the report of suspected dengue cases. Two categories of plantations were selected for the study, plantations where active tapping was going on using rain guards and those where the tapping was suspended. Ten plantations each were selected under each category from both districts. In each plantation, 100 trees were surveyed at random for mosquito breeding. There was no mosquito breeding in the first category of plantations. In the second category, profuse breeding of mosquitoes was encountered in 98.3% of the latex cups filled with rainwater. *Aedes albopictus* emerged from all samples.[3]

Another study in 2007 also reported the importance of latex cups as a major breeding habitat of *Aedes albopictus* in Kerala. Of the total positive container habitats with *Aedes albopictus* detected in a survey conducted in Alleppey, Ernakulam, Kottayam, Thrissur, and Thiruvananthapuram districts, 79.7% were latex cups in Rubber plantations. They also reported the detection of dengue virus antigen from the adult mosquitoes that emerged from the samples collected from latex cups.[9]

In an elaborate survey conducted from June 2005 to September 2010 in the rubber plantations of Kannur, Wayanad, and Kozhikode districts of Kerala, 12 species of mosquitoes belonging to 6 genera, viz., *Aedes albopictus, Ae. chrysolineatus, Ae. cogilli, Ae. gubernatoris, Ae. harveyi, Ae. subalbopictus, Armigeres subalbatus, Culex brevipalpis, Cx. uniformis, Heizmannia chandi, Toxorhynchites splendens,* and *Verrallina* species were detected from latex cups. These species were found breeding alone as well as in association with other species. The association of species was observed in 20 different combinations, with a maximum of 5 species in one combination. Except in one all combinations had *Aedes albopictus* as a common species.[10]

While conducting larval surveys in the rubber plantation belt of Kottayam and Idukki districts of Kerala from February 2008 to January 2011, researchers claimed to have detected 12 species of mosquitoes breeding in latex cups. However, they did not specify the species collected from the latex cups separately.[11]

Breeding of *Aedes* mosquitoes in latex cups was also observed in the rubber plantations of Malappuram district of Kerala during a survey in 2018. However, the authors did not indicate the species.[12]

Besides Kerala, the neighbouring Tamil Nadu state also has rubber plantations, especially Kanyakumari district. In a 2019 study in the district, the breeding of *Aedes albopictus* was detected in the latex cups. This was the first report of this kind from Tamil Nadu. The survey for the dengue vector *Aedes albopictus* was done in some selected villages of Kalkulam Taluk of Kanyakumari district from June 2019 to December 2019. Coconut shells were used for collecting latex in these villages. Aedes breeding was observed in most of the shells surveyed and all emerged adults were Aedes albopictus.[13]

In the same year, the pattern of *Aedes albopictus* breeding in the latex cups in the Palakkad district of Kerala during the pre-monsoon and monsoon periods was reported. Of the total container habitats surveyed, latex cups constituted 82.1%, of which 35.4% had breeding of *Aedes albopictus.*[14]

In 2016, larval surveys in association with a serological survey for dengue virus were conducted in two rural and one urban area of Kottayam district. Profuse breeding of *Aedes albopictus* was encountered in both used and discarded latex cups to the extent of 40.08%.[15]

Lao PDR

Lao PDR's contribution to rubber cultivation is rather minor with an area of approximately 1,47,000 ha only. However, plantations in Northern Lao PDR were reported to support mosquito breeding in a large way. In a 2018 report, the breeding of *Aedes albopictus* in latex cups was recorded in this country. Out of 1379 water bodies surveyed

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between August to December 2014, 724 were positive for mosquito breeding, from which 3757 adults emerged of which 2845 were *Ae.albopictus*. 20% of the *Ae. albopictus* adults emerged from latex cups.[16]

Indonesia

Indonesia has the largest area under rubber cultivation in the world. However, there are not many studies related to mosquito breeding in rubber plantations. In a 2021 study on the dynamics of the *Toxorhynchites splendens* population in the larval phase in the rubber plantations of Banjarbaru, South Kalimantan, the presence of other mosquito larvae in latex cups, with and without *Tx. splendens larvae*, has been mentioned. However, there is no mention of the species of the other mosquitoes. The study was done in 10 localities from April to October 2020. From April to July, 48–83% of latex cups surveyed had *Toxorhynchites splendens* larvae. This was 20–31% between August and September and 7–25% in October.[17]

African Countries

African countries' share in global rubber cultivation is only 9.6%. Among ten rubber-cultivating countries in the continent, so far only Liberia and Ivory Coast reported mosquito breeding in latex cups.

Liberia

The first observation of mosquito breeding in latex cups was done in 1958 in Liberia. This was the second such observation in the world. Following this observation, an experiment was conducted in the Firestone rubber plantation at Harbel. In this experiment, latex cups were placed upright on rubber trees. Half of the cups were filled with distilled water and the remaining half with rainwater. Observations were made from May to December 1958. Besides these oriented cups, mosquito larvae were collected from accidentally upturned cups in natural condition. From the experimental cups, 10 species of mosquitoes belonging to 3 genera could be collected. They were *Aedes apicoargenteus, Ae. frazeri, Ae. schwertzi, Ae. aegypti, Ae. simpsoni, Culex nebulosus, Cx. macfei, Cx. horridus, Cx. tritaeniorhynchus,* and *Eretmapodites chrysogaster*. Among them *Cx. macfei, Cx. horridus and Cx. tritaeniorhynchus* were found breeding only in distilled water. In addition, eight species were found breeding in accidentally upturned cups. They were *Aedes africanus, Culex ingrami, Cx. decens, Lutzia tigripes, Eretmapodites oedipodius, Er. Leucopus, Anopheles gambiae, and Toxorhynchites brevipalpus.*[18]

Ivory Coast

During a mosquito survey undertaken in the southeastern Ivory Coast in 2014 to study the effect of land-use changes on the abundance, distribution, and host-seeking behaviour of *Aedes* arbovirus vectors in oil-palm-dominated landscapes, *Aedes* breeding was observed in latex cups. Though the exact species was not indicated, *Aedes aegypti* was mentioned as the predominant species.[19] Subsequently, larval surveys conducted from November 2015 to December 2016 in two rubber production areas Bongo and Toupah of Southern Ivory Coast revealed latex cups as the predominant habitats that supported mosquito breeding. In both areas, latex cups were the most productive; 53.7% in Toupah and 44.5% in Bongo. *Aedes aegypti* was the predominant species in both areas. *Besides Aedes species*, the breeding of Anophelines and Culicines was also encountered.[20] Further, entomological surveys conducted in the rubber plantations of Dabou from January to June 2017 showed that the major mosquito breeding sites in matured rubber plantations were latex cups (N = 332, 96.2%). They were found harbouring *Aedes aegypti* and *Culex quinquefasciatus* among several other species. Though 27 species were claimed to be recorded from various habitats in the study area, species-wise distribution has not been indicated. Hence, it is not clear which species other than *Aedes aegypti* and *Culex quinquefasciatus* were breeding in them.[21]

Correlation with Mosquito-Borne Diseases

So far six established disease vectors have been reported breeding in latex cups, viz., *Aedes aegypti, Ae. albopictus*, *Ae. africanus*, *Anopheles gambiae*, *Cx. quinquefasciatus*, and *Cx. tritaeniorhynchus* (Table 1). However, barring one, there have not been any studies specifically linking these vector species breeding in rubber plantations to disease transmission. In a study conducted in 2007, dengue virus antigen was detected in the adult mosquitoes that emerged from the samples collected from latex cups from South Kerala.[9]

Conclusion

From the above discussion, it is amply evident that rubber plantations, especially latex cups, play a major role in the proliferation of mosquitoes. Altogether 30 species of mosquitoes belonging to 9 genera were reported to breed in these habitats. *Aedes albopictus*, the vector for dengue, chikungunya, and Zika was the predominant species in Asian countries. In African countries, these habitats predominantly supported the breeding of *Aedes aegypti*. Besides this principal vector of yellow fever and dengue, the breeding of other vector species viz., *Aedes africanus* (yellow fever), *Anopheles gambiae* (malaria), *Culex quinquefasciatus* (lymphatic filariasis), and *Cx. tritaeniorhynchus* (Japanese Encephalitis) was also encountered.

Since mosquito breeding in latex cups is associated with the rainy season, it is recommended to remove the cups from rubber trees prior to the stoppage of latex tapping. It was also reported that latex tapping during rainy seasons using rain guards did not show mosquito breeding. Hence,

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it was recommended to encourage tapping during rainy seasons if economically viable.[3]

In spite of the importance of these unique habitats, the survey of the literature reveals that studies on rubber plantations as mosquito breeding ecosystems are very scarce. Despite having similar climatological conditions as those of India, Indonesia, and Malaysia, the major rubber-producing countries in Asia viz., Thailand, Vietnam, Cambodia, and Sri Lanka have never reported the status of rubber plantations vis a vis mosquito breeding. The situation is similar in African and South American countries. Hence, a global initiative is proposed to investigate the status of mosquito breeding in the rubber plantations of all rubber-growing countries in the world.

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