How Climate Changes Affects Mosquito Vector Competence in Dengue Virus Spread

Lintan Kurnia Farizqi[1]

[1]Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jawa Timur, Surabaya, Indonesia

Corresponding Author

Lintan Kurnia Farizqi

Faculty of Medicine Universitas Pembangunan Nasional Veteran Jawa Timur

Rungkut Madya Street Number 191, Rungkut Kidul, Rungkut District, Surabaya, Jawa Timur 60293

Tel/Fax: +628113111846

E-mail: lintan.kurnia.farizqi.fk@upnjatim.ac.id

Abstract

Background The impacts of climate change are currently increasing rapidly, largely due to greenhouse gas emissions from burning fossil fuels. Climatic conditions such as increased temperature, rainfall patterns affect the survival, development and geographical distribution of Aedes mosquitoes as well as their ability to transmit dengue virus known as vector competence. Dengue fever is transmitted by Aedes aegipty and Aedes albopictus mosquitoes. More than 10 million case if dengue fever have been reported. Climate change can accelerate the life cycle of mosquitoes, reducing the time it takes for the virus to develop inside the mosquito, increasing infection in the vector thus increasing the potential for dengue fever transmission.

Methods This study uses the literature review method using the Google Scholar,Pubmed ans Science Direct databased using the keywords "climate change", "vector competence", "dengue fever"," Aedes aegypti","Aedes albopictus".

Result Total 498 literature were found (from Science direct, Pubmed, and Google Scholar) then 9 articles were selected according to the specified topics and criteria.

Conclusion Climate change has a significant impact on vector competence in Aedes mosquitoes in dengue virus transmission so that strategies in dengue fever control are needed.

Keywords. Dengue, Climate change, *Aedes aegypti, Aedes albopictus.*

Introduction

The impacts of climate change are now increasing rapidly, largely due to greenhouse gas emissions from burning fossil fuels. The global average temperature has increased by 1,1 ºC since 1900 with most of the change occuring within the last 50 years. Global climate change affects the transmission dynamics of diseases including dengue fever. Climatic conditions such as increased temperature, rainfall paterns affect the survival, develompment and geographical distribution of Aedes mosquitoes and their ability to transmit dengue virus known as vector competence.[1,2]

Dengue fever is an acute infection caused by one of four dengue virus serotypes (DEN-1, DEN-2, DEN-3, DEN-4) transmitted by Aedes aegypti and Aedes albopictus mosquitoes. Transmission of the disease is rapid and causes high morbidity and mortality. The mojority of infected individuals are asymptomatic or experience only mild symptoms such as high fever, headache, skin rash, muscle and joint pain. Some cases can be aggravated resulting in severe bleeding and complication leading to death.[1]

The years 2024 is the worst year for dengue fever, as of July 23, 2024 more the 10 milion cases of dengue fever have been reported in 176 countries with 24.000 cases and 6508 death. This figure already exceeds the number of cases in 2023. Dengue is the only disease with a mortatily rate that increases every year with 80% of infections being asymptomatic or causing mild symptoms. The arrival of the rainy season in the tropics is one of the reasons for the sharp increase in dengue cases.

Recent research explains that an increase in ambient temperature can accelerate the life cycle of mosquitoes, reducing the time needed for the virus to develop in the mosquito's body, increasing infection in the vector and thus increasing the potential for dengue fever transmission.[3]

Rainfall changes can increase vector populations and expand the area of virus spread. As climate change patterns continue, it is expected that dengue endemic areas will expand and increase the risk of dengue infection.[4] To understand about the relationship between climate change and vector competence in Aedes mosquitoes is crucial in the development of mitigation strategies and to reduce future disease burden. This study will discuss how climate change can affect the ability of Aedes mosquitoes to transmit dengue virus through a literature review.

Methods

The research method used in this article is the literature review method to determine the impact of climate change on vector competence in Aedes mosquitoes in dengue fever

transmission. The authors conducted a data search using PubMed, Google Scholar and Science direct databases. The keywords used were "climate change", "vector competence", "dengue fever", "Aedes aegypti", "Aedes albopictus". The keywords were combined with "AND" and "OR" to search for relevant literature. The results of the data search are presented in the form of a PRISMA diagram. The inclusion criteria for this article are articles published in 2019-2024, research articles in English, available in full text, open access. The exclusion criteria for this article are articles published outside 2019-2024, articles not using English, full text not available and non-open access.

Result

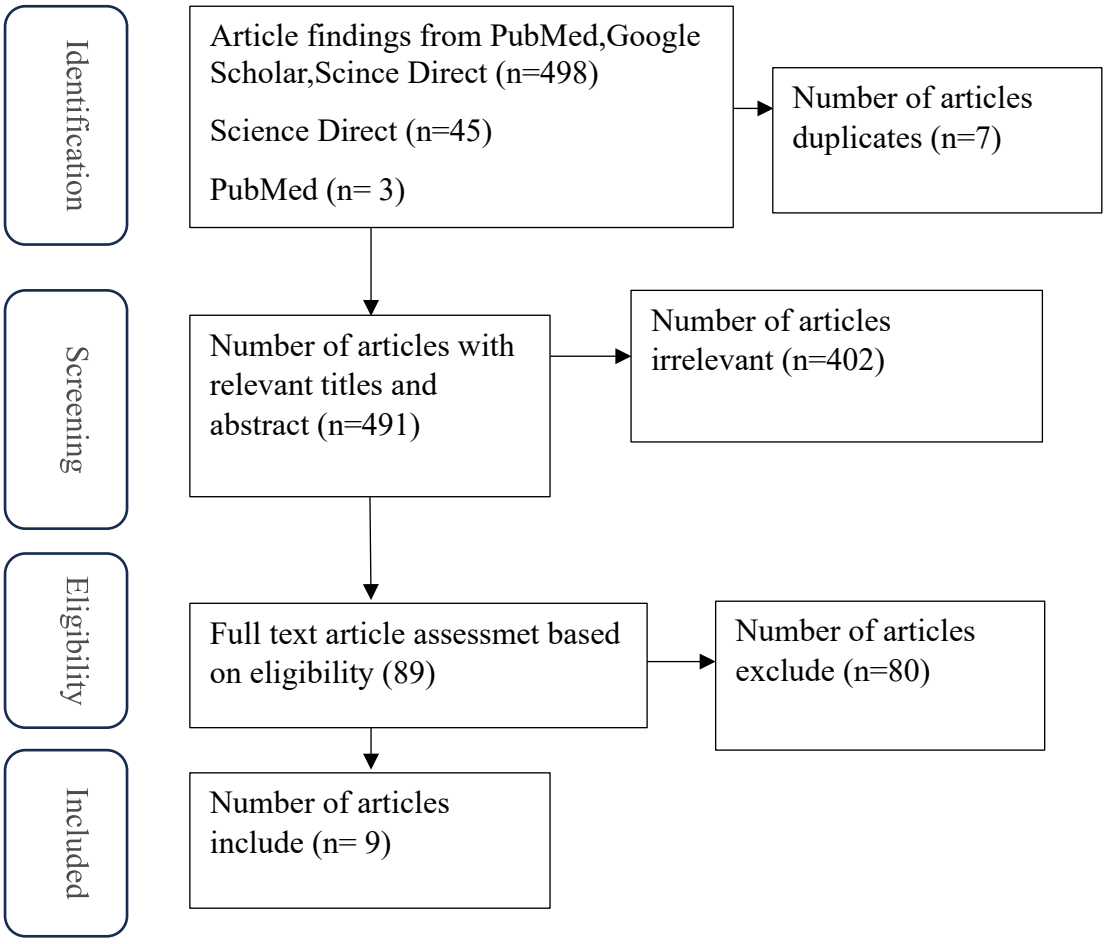

Figure 1 Diagram of selection and evaluation based on PRISMA diagram Flow

Literature search on Science Direct database as many as 45 articles, Google Scholar 450 and PubMed as many as 3 articles with a total of 498 articles from the data base. Then the article is selected based on the specified criteria with the final result of 9 articles that match the criteria.

Table 1. Studies Characteristics

No	Judul	Referensi	Hasil
1	**Do we know how mosquito disease vectors will respond to climate change?**	[1]	Higher temperatures accelerate the development of pathogens in the mosquito's body, reduce the extrinsic incubation period, and increase the frequency of mosquito bites, which in turn may increase the risk of disease transmission.
2	**The effect of temperature on dengue virus transmission by *Aedes* mosquitoes**	[8]	Temperature plays an important role in the replication of dengue virus in the body of Aedes mosquitoes. Warm temperatures accelerate the replication of the virus in mosquitoes
3	**Climate change and the rising infectiousness of dengue**	[9]	Increasing global temperatures have the potential to increase the vector competence of Aedes mosquitoes to transmit the dengue virus.
4	**Effects of Guangzhou seasonal climate change on the development of *Aedes albopictus* and its susceptibility to DENV-2**	[10]	*Aedes albopictus that thrive at higher temperatures show increased susceptibility to DENV-2 infection. Warmer temperatures during the larval and adult stages of development increase vector competence, or the mosquito's ability to acquire, support replication, and transmit dengue virus.*
5	Transmission dynamics of dengue and chikungunya in a changing climate: do we understand the eco-evolutionary response?	[11]	Dengue, chikungunya and several other mosquito-borne diseases are sensitive to changes in climate (e.g., extrinsic incubation period, habitat suitability) and pathogen (e.g., viral replication rate). Vector competence has been shown to depend on mean temperature and diurnal temperature range, which represents the variation in temperature within a day.

No	Judul	Referensi	Hasil
6	**Vector Competence for DENV-2 Among *Aedes albopictus* (Diptera: *Culicidae*) Populations in China**	[12]	There is significant variation in vector competence among different *Aedes albopictus* populations in China. Some mosquito populations show higher levels of DENV-2 infection and transmission than others.
7	**Impact of past and on-going changes on climate and weather on vector-borne diseases transmission: a look at the evidence**	[13]	Temperature and humidity affect the interaction between vectors and pathogens, changes in temperature can accelerate biological processes in the life cycle of pathogens thereby affecting the ability to transmit disease.
8	**Estimating the risk of arbovirus transmission in Southern Europe using vector competence data**	[15]	Climate change affects the transmission capacity of arboviral diseases and influences the life cycle of pathogens.
9	**Impact of temperature on dengue and chikungunya transmission by the mosquito *Aedes albopictus***	[14]	The microbiota in the mosquito body plays an important role in determining vector competence, changes in temperature can affect commensal bacteria and trigger arbovirus infections towards the mosquito intestinal epithelium.

Discussion

Vector competence is the ability of a mosquito to become infected by a pathogen and then transmit it to a new host.[18] A wide range of biological and environmental factors can influence this vector competence in mosquitoes. When the virus is found in the gut of a mosquito, the mosquito is considered infected, if the virus is found in the salivary glands and saliva of the mosquito, the mosquito is considered capable of transmitting the virus.[9]

Vector competence has been shown to depend on average temperature and diurnal

temperature range, which represents the variance of temperature within a day.[9] Climate change is an important global issue in recent years, impacting all aspects of human life, including health. Vector-borne diseases may be particularly affected by climate change. Current climate change is likely to lead to widespread geographical distribution of several mosquito-borne diseases, especially dengue fever, associated with changes in temperature, precipitation and humidity.[7]

In the case of mosquito-borne virus transmission, the extrinsic incubation period (EIP) is strongly influenced by temperature, vector competence is a key factor in the vector's ability to transmit disease which is genetically determined and modulated by climate. Insects are cold-blooded or pyocillothermic organisms that cannot regulate their own body temperature, because body temperature is important for achieving biochemical reactions for development and physiological functions so that insects are very dependent on ambient temperature.[9]

Based on the research of Andriamifidy et al., mentioned that high temperatures tend to higher temperatures tend to accelerate the development of pathogens in the mosquito body, reduce the extrinsic incubation period, and increase the frequency of mosquito bites, which in turn can increase the risk of disease transmission.

The results of several studies suggest temperature changes play an important role in dengue virus transmission by Aedes mosquitoes. The minimum temperature suitable for DEV transmission is 14.8°C while the optimal maximum temperature is between 22°C to 33°C, but it cannot survive when the temperature is around 40°C.[19]

This is supported by the research of Tozan et al., (2020) the process of virus development in the mosquito body includes several physiological processes and is related to the accumulation of temperature and heat. When a mosquito sucks the blood of a dengue infected human, the virus replicates in the mosquito's midgut before spreading to other tissues, including the salivary glands.[9]

The time required from virus entry to transmission to a new host is called the extrinsic incubation period (EIP). The EIP takes about 8-12 days when the temperature is between 25-28°C. Variations in the extrinsic incubation period are not only influenced by ambient temperature, several other factors such as daily temperature fluctuations, viral genotype and initial virus concentration can alter the time required for mosquitoes to transmit the virus. Some studies have shown that the Extrinsic Incubation Period (EIP) decreases as the temperature increases from the threshold.[9]

Aedes albopictus is the main vector of DENV transmission in certain areas due to its wide distribution. When the temperature drops below 18°C, Aedes albopictus does not

transmit DENV but can transmit chikungunya virus.[20] The ability of Aedes albopictus to transmit DENV increases as the temperature increases between 18°C and 32°C. However, when temperatures exceed 32°C, the mortality rate of Aedes albopictus increases, potentially reducing its vector competence.[8] Temperature also affects the ability of the virus to pass through the midgut barrier. DENV-2 resides in the midgut of Aedes albopictus and multiplies at 18°C. However, DENV-2 successfully penetrates the midgut barrier and invades the salivary glands between 23°C and 32°C.

Temperature also plays an important role in regulating dengue virus replication within the Aedes mosquito, warm temperatures accelerate virus replication within the mosquito. Significant temperature differences between day and night can affect vector competence, at lower average temperatures (<18°C), temperature fluctuations of 6.26°C between day and night increase the ability of Ae.aegypti to infect and transmit DENV-1 [21]. In a study by Liu et al., 2023, at higher average temperatures (≥18°C), the same temperature fluctuations between day and night reduced the vector competence of Ae. Aegypti vector.[21]

Liu et al. (2023) showed that the RNAi pathway in Aedes aegypti mosquitoes is disrupted at low temperatures making mosquitoes more susceptible to the virus compared to mosquitoes in colder areas, in addition, disruption of the RNAi pathway increases the titer of DENV-2 in the midgut this facilitates the spread of the virus to other tissues and shortens the EIP. In addition, Aedes aegypti activates the γ-aminobutyric acid (GABA)-related system through blood feeding, increasing DENV-2 replication by inhibiting the IMD pathway.[8]

According to Rocklov et al. research, (2019) climate change significantly increases the potential for dengue transmission, by expanding the breeding area of mosquitoes, increasing their ability to reproduce rapidly, accelerating the life cycle of the virus in the mosquito's body and expanding the geographical area suitable for dengue transmission. In addition, climate change also extends the dengue transmission season in many regions and the greatest impact is felt in the tropics and subtropics.

Wu et al. (2022) showed that a combination of environmental factors such as temperature, nutrients and genotypes of viruses and mosquitoes determine the efficiency of a vector in transmitting a disease.

The mosquito innate immune response is a major determinant of successful virus transmission that triggers the activation of innate immunity including the RNA interference (RNAi) pathway, JAK STAT pathway, Toll pathway and Immunodeficiency Pathway (IMD) leading to the transcription of genes responsible for the antiviral response.[10]

Temperature is an important factor affecting the ability of DENV-2 to infect the Aedes albopictus vector (18-32°C). The higher the temperature, the faster the virus multiplies in Aedes albopictus,easier to penetrate the midgut barrier, and the shorter the time it takes to spread to the ovaries and salivary glands .

Vector competence for DENV in Aedes mosquitoes is influenced not only by ecological structure, climate, virus titer, and DENV serotype and virulence, but also by endosymbiont bacteria and mosquito genetic factors. Susceptibility to dengue virus in different mosquito species differs significantly, as does the susceptibility of different geographic strains of the same mosquito species.[10] According to research by Meercier et al., (2022) temperature changes can affect microbes in the mosquitoes body such as protozoa, fungi, bacteria and viruses that play a role in protection against pathogens.

Mosquito microbiota plays an important role in stopping differences in vector competence. At 20°C, some essential bacteria can trigger arbovirus invasion so that the virus can easily enter the intestinal epithelium of mosquitoes.[14] From the data above, high ambient temperature can increase virus multiplication and reduce the extrinsic incubation period so that the virus can multiply in the vector's body and then reach the salivary glands so that it can be transmitted to other hosts, on the other hand, relative humidity increases mosquito survival so that mosquitoes can survive long enough until the extrinsic incubation period of the virus is complete and allows virus transmission.[17]

Conclusion

This article shows that climate change has a significant impact on vector competence in *Aedes* mosquitoes in transmitting dengue virus. Increased temperature, humidity and changes in rainfall patterns can increase the risk of dengue outbreaks. The immunity factors of *Aedes* mosquitoes change after being infected with DENV at different temperatures. Changes in rainfall can create more breeding habitats, supporting mosquito populations and the potential for virus spread. Knowledge of vector competence can help design strategies for targeted dengue control such as monitoring high-risk mosquito populations and targeted interventions to reduce virus transmission.

References

1. Bifani AM, Siriphanitchakorn T, Choy MM. Intra-host diversity of dengue virus in mosquito vectors. Front Cell Infect Microbiol. 2022;12:888804.
2. Ryan SJ, Carlson CJ, Mordecai EA, Johnson LR. Global expansion and redistribution of Aedes-borne virus transmission risk with climate change. PLoS Negl Trop Dis. 2019;13(3):e0007213.
3. Mordecai EA, Cohen JM, Evans MV, Gudapati P, Johnson LR, Miazgowicz K, et al. Thermal biology of mosquito-borne disease. Ecol Lett. 2020;22(10):1690-1708.
4. Colón-González FJ, Sewe MO, Tompkins AM, Sjödin H, Casallas A, Rocklöv J, et al. Projecting the risk of mosquito-borne diseases in a warmer and more populated world: a multi-model, multi-scenario intercomparison modelling study. Lancet Planet Health. 2021;5(7):e404-e414.
5. Messina JP, Brady OJ, Golding N, Kraemer MUG, Wint GRW, Ray SE, et al. The current and future global distribution and population at risk of dengue. Nat Microbiol. 2019;4(9):1508-1515.
6. Colón-González FJ, Harris I, Osborn TJ, Steiner São Bernardo C, Peres CA, Hunter PR, et al. Limiting global-mean temperature increase to 1.5–2°C could reduce the incidence and spatial spread of dengue fever in Latin America. Proc Natl Acad Sci USA. 2021;118(22):e2016973118.
7. Naish S, Dale P, Mackenzie JS, McBride J, Mengersen K, Tong S. Climate change and dengue: a critical and systematic review of quantitative modelling approaches. BMC Infect Dis. 2014;14:167.
8. Liu Z, Zhang Q, Li L, He J, Guo J, Wang Z, et al. The effect of temperature on dengue virus transmission by Aedes mosquitoes. Front Cell Infect Microbiol. 2023;13:1242173.
9. Rocklöv J, Tozan Y. Climate change and the rising infectiousness of dengue. Emerg Top Life Sci. 2019;3(2):133-142.
10. Wu S, He Y, Wei Y, Fan P, Ni W, Zhong D, et al. Effects of Guangzhou seasonal climate change on the development of Aedes albopictus and its susceptibility to DENV-2. PLoS One. 2022;17(4):e0266128.
11. Tozan Y, Sjödin H, Munoz AG, Rocklöv J. Transmission dynamics of dengue and chikungunya in a changing climate: do we understand the eco-evolutionary response? Expert Rev Anti Infect Ther. 2020;18(12):1187-1193.
12. Wei Y, Wang J, Wei YH, Song Z, Hu K, Chen Y, et al. Vector competence for DENV-

2 among Aedes albopictus (Diptera: Culicidae) populations in China. Front Cell Infect Microbiol. 2021;11:649975.

13. Fouque F, Reeder JC. Impact of past and on-going changes on climate and weather on vector-borne diseases transmission: a look at the evidence. Infect Dis Poverty. 2019;8:51.
14. Mercier A, Obadia T, Carraretto D, et al. Impact of temperature on dengue and chikungunya transmission by the mosquito Aedes albopictus. Sci Rep. 2022;12:6973.
15. Mariconti M, Obadia T, Mousson L, et al. Estimating the risk of arbovirus transmission in Southern Europe using vector competence data. Sci Rep. 2019;9:17852.
16. Chen TY, Bozic J, Mathias D, et al. Immune-related transcripts, microbiota and vector competence differ in dengue-2 virus-infected geographically distinct Aedes aegypti populations. Parasit Vectors. 2023;16:166.
17. Chepkorir E, Lutomiah J, Mutisya J, et al. Vector competence of Aedes aegypti populations from Kilifi and Nairobi for dengue 2 virus and the influence of temperature. Parasit Vectors. 2014;7:435.
18. Souza-Neto JA, Powell JR, Bonizzoni M. Aedes aegypti vector competence studies: A review. Infect Genet Evol. 2019;67:191-209.
19. Marinho RA, Beserra EB, Bezerra-Gusmão MA, Porto Vde S, Olinda RA, Dos Santos CA. Effects of temperature on the life cycle, expansion, and dispersion of Aedes aegypti (Diptera: Culicidae) in three cities in Paraiba, Brazil. J Vector Ecol. 2016;41(1):1-10.
20. Wimalasiri-Yapa BMCR, Stassen L, Huang X, Hafner LM, Hu W, Devine GJ, et al. Chikungunya virus in Asia-Pacific: a systematic review. Emerg Microbes Infect. 2019;8(1):70-79.
21. Carrington LB, Armijos MV, Lambrechts L, Scott TW. Fluctuations at a low mean temperature accelerate dengue virus transmission by Aedes aegypti. PLoS Negl Trop Dis. 2013;7(4):e2190.