

LeO-Trap: Application of the lethal ovitrap for controlling vectors of dengue fever in Chiang Mai province, Thailand

Suttida Suwannayod¹ Usavadee Thavara² Navy Srivarom² Payu Bhakdeenuan²
Apiwat Tawatsin² Padet Siriyasatien^{3*}

Abstract

Mosquito-borne diseases transmitted by *Aedes* mosquitoes in Thailand, including dengue hemorrhagic fever, chikungunya, and zika viruses, are major health concerns. To address this, the LeO-Trap is an ovitrap with the potential for controlling disease vectors. This research aimed to assess the effectiveness of the LeO-Trap in a high-risk urban area in Chiang Mai province, Thailand. The study area chosen, due to the number of dengue cases, encompassed two villages in Mae Rim district, each with over 100 homes. From May to July 2021, four LeO-Traps were deployed in every home - two indoors and two outdoors. Ovitrap Index (OI) and House Index (HI) were calculated for mosquito eggs over two months. Statistical analysis included a t-test for significance, marked at $p < 0.05$. In the urban area of Mae Rim, the OI of Village 1 (Moo.2) decreased from 70.54% to 44.49%, and HI from 89.15% to 58.13%. The OI of Village 2 (Moo.10) dropped from 80.10% to 70.31%, while the HI went down from 94.17% to 78.31%. Interestingly, the monthly egg counts within each village showed significant differences ($p < 0.05$). In conclusion, the LeO-Trap is promising as an innovative ovitrap for monitoring and controlling *Aedes* mosquitoes. Its effectiveness offers a reliable approach that benefits human health and the environment. This research sheds light on its potential to address the challenge of controlling mosquito-borne diseases in the Mueang Chiang Mai district in Thailand.

Keywords: Ovitrap, LeO-Trap, Dengue fever, *Aedes* spp., Chiang Mai

¹International College of Digital Innovation, Chiang Mai University, Chiang Mai 50200, Thailand

²Department of Medical Sciences, Ministry of Public Health, Nonthaburi 11000, Thailand

³Center of Excellence in Vector Biology and Vector Borne Diseases, Department of Parasitology, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand

*Correspondence: padet.s@chula.ac.th (P. Siriyasatien)

Received January 4, 2024

Accepted August 18, 2024

Introduction

Mosquitoes, specifically *Aedes (A.) aegypti* (L.) and *Ae. albopictus* (Skuse) is acknowledged as the principal mosquito vector responsible for transmitting diseases such as dengue, yellow fever, chikungunya, zika, and numerous other arboviruses (WHO, 2012). These diseases pose significant public health challenges in numerous countries located within tropical and sub-tropical regions. In Thailand, the occurrence of dengue fever has been observed consistently since 1949 (Office of Dengue Control, 2002). Notably, the disease made a significant rise in 2013, reaching its peak with a total of 154,733 reported cases (Ministry of Public Health, 2017). The cumulative of dengue cases reached 73,979, including 3,287 new ones, from January 1st to September 28th, 2023, and 68 deaths were reported. So far, in 2023, the number of patients has been 3.3 times greater than in the same period of 2022 (Department of Disease Control, 2023). In Chiang Mai province, a total of 2,316 dengue cases were reported from January to September 2023, with an incidence rate of 117.51 cases per 100,000 population, and the highest occurrences among the 5-9-, 10-14-, and 25-34-year age-groups and there were three deaths. The areas by district with the highest prevalence were Mueang Chiang Mai, Mae Ai, Fang, Chiang Dao, and Mae Rim. In this regard, reducing the vector mosquito population plays a crucial role in lowering the incidence of dengue fever. As there is no effective vaccine for preventing dengue fever, the primary method employed is vector control by managing mosquitoes through various strategies such as chemical, biological, and physical approaches (Pujol, 2011). These control methods have not achieved the level of success necessary for effectively preventing dengue fever. In addition, the utilization of insecticides has been constrained by increasing apprehension about potential negative impacts on human health, the environment, and non-target organisms. Prior studies have shown that various vector mosquitoes, including *Ae. aegypti* and *Ae. albopictus* tend to develop resistance to insecticides, particularly pyrethroids (Chareonviriyaphap et al., 2013).

Synthetic chemical insecticides are commonly used as an effective method for directly controlling vectors (Mehlhorn et al., 2014). Chemical compounds have the potential to protect individuals from mosquito bites by inducing either mosquito mortality or obtaining excito-repellency, an incident that disrupts or inhibits the mosquito's normal feeding behavior (Roberts and Andre, 1994). In Thailand, various synthetic pyrethroids, such as deltamethrin, cyfluthrin, bifenthrin, α -cypermethrin, and permethrin, have been available on the public market to control *Ae. aegypti* mosquitoes (Somboon et al., 2003; Thanispong et al., 2010). Chemical insecticides such as organophosphates, carbamates, and pyrethroids have been employed frequently for adult mosquito control, while these substances, alongside insect growth regulators, have been used as larvicides in aquatic environments. Nonetheless, excessive usage leads to the development of insecticide resistance within mosquito populations (Brown and Hebert, 1997; Qiu et al., 1998; Rivero et al., 2010).

Therefore, the utilization of insecticides has faced obstacles due to the increasing negative impacts on human health, the environment, and non-target organisms. Consequently, appropriate devices that reduce insecticide usage, as opposed to widespread application, emerge as a crucial concept in the control of *Aedes* mosquitoes. Currently, there are methods in place to control the mosquito population, including the use of the LeO-Trap, which has served as a tool for surveillance and monitoring *Aedes* mosquitoes in endemic regions. Additionally, its potential extends to transformation into a lethal ovitrap for the control of *Aedes* larvae and adults when integrated with larvicides or adulticides. Many investigations into the efficacy of lethal ovitraps were conducted, both in laboratory settings (Zeichner and Perich, 1999; Parker et al., 2017) and in field conditions (Sithiprasasna et al., 2003; Williams et al., 2006; Williams et al., 2007; Barrera et al., 2014; Johnson et al. 2017), as a means of controlling *Aedes* populations. LeO-Trap is the recently developed lethal ovitrap that combines a visually appealing design with biochemical attractants and larvicides. It originated from the Department of Medical Science in Thailand (Tawatsin et al., 2019). The biochemical compounds, extracted from carpet shells and giant tiger prawn rinses, function as oviposition attractants for *Ae. albopictus* mosquitoes in both controlled laboratory environments and natural field conditions. These attractants were employed in activities aimed at monitoring and managing mosquito populations (Thavara et al., 2004). Many studies have affirmed that LeO-Traps can effectively and significantly decrease mosquito populations in Thailand (Molito et al. 2020; Sapcharoen et al. 2021). In addition, LeO-Traps play a role in controlling the larvae hatched from eggs. These traps are equipped with zeolite granules containing 1% temephos, aimed at eliminating mosquito larvae. This strategy aids in reducing the populations of both mosquito larvae and adult mosquitoes in households where these egg traps are utilized (Sevana et al., 2021). This study aimed to evaluate the effectiveness of the LeO-Trap in the reduction of mosquito vectors in the high-risk urban areas of Chiang Mai province, Thailand. Additionally, based on feedback from the villagers, the study will implement the LeO-Trap, which has been laboratory-tested and proven effective in attracting mosquitoes to lay eggs.

Materials and Methods

Study areas: The high-risk zone for potential dengue outbreaks was selected based on the 2016-2020 dengue projection report from the Division of Vector Borne Disease, Department of Disease Control. Mae Rim district was designated the high-risk zone [It is an assessment of dengue fever risk conducted by the Department of Disease Control, Ministry of Public Health. The assessment identifies districts with high incidence rates over the past five years (2016-2020) (Department of Disease Control, 2020)] within Chiang Mai province, and two villages in the Don-Kaew sub-district, Village 1 (Moo.2); 130 households and Village 2 (Moo.10); 103 household having elevated risk levels were selected for this study. The rainfall history was

recorded by The Chiang Mai Meteorological Station in 2020.

Ovitrap preparation and mosquito egg monitoring:

The Leo-Trap used in this study was developed using carpet shell extract as an attractant and larvicide (Thavara et al., 2004). The larvicide applied in this study consisted of zeolite granules containing 1% w/w temephos as the active ingredient, branded as AZAI®. Ovitrap were opened, and the cover was filled with clean water, keeping the water level about half an inch below the top edge of the overflow hole. Then, add AZAI® approximately half a teaspoon (It is effective in eliminating *Aedes* mosquito eggs for up to 3 months). Add more water every 15 days and change the solution after 3 months. The ovitraps for collection of *Aedes* spp. eggs were equipped with sponge sheets around their interior. The survey of *Aedes* mosquito eggs involves placing Leo-Trap, with two traps inside the house and two traps outside the house per household in the two villages. The trap locations are chosen randomly, with indoor traps placed in dark, secluded areas and outdoor traps placed in areas with dense trees. Volunteers conducted surveys to assess the prevalence of mosquito eggs at the one-month and two-month after placement. They also retrieved the sponge sheets from the ovitraps to count the mosquito eggs, aided by a magnifying glass with 3x magnification.

Data analysis: The collected data underwent analysis to determine outcomes for several indicators as outlined below:

1. Surveillance of mosquito egg abundance (Brown, 1973)

$$\text{Ovitrap Index (OI)} = \frac{\text{number of ovitraps found positive with mosquito eggs}}{\text{Total number of ovitraps used}} \times 100$$

$$\text{House Index (HI)} = \frac{\text{number of houses positive with mosquito eggs}}{\text{Total number of houses surveyed}} \times 100$$

2. Rate of mosquito eggs deposited = $\frac{\text{Number of mosquito eggs}}{\text{Total number of ovitraps}} \times 100$
3. Number of mosquitoes eradicated = $\frac{\text{number of mosquito eggs}}{2} \times 500$

(A single female *Aedes* mosquito can lay up to 500 eggs, and approximately half of the emerging adults are female mosquitoes that feed on blood and spread diseases.) (Department of Medical Sciences, 2021).

Comparison between the quantities of *Aedes* eggs found indoors and outdoors was conducted through a t-test, employing a significance level of $\alpha = 0.05$.

Result

Assessment of the prevalence index for *Aedes* eggs:

After implementing the LeO-Trap for one month (July 2021), the results showed the Ovitrap Index (OI) standing at 70.54% and House Index (HI) at 89.15% in Village 1 (Moo.2), and at 80.1% for OI and 94.17% for HI in Village 2 (Moo.10). At the end of the second month, which was August 2021, the prevalence index of *Aedes* mosquito was reevaluated. The findings revealed that the OI had decreased to 44.49% and HI to 58.13% in Village 1 (Moo.2), and similarly, the OI decreased to 70.31% and HI to 78.31% in Village 2 (Moo.10) (Table 1).

Between July and August 2021, *Aedes* eggs on the sponge sheets were counted both indoors and outdoors. The results indicated no statistically significant difference between the two villages in terms of egg count ($p > 0.05$). Nonetheless, it is possible to calculate the number of adult *Aedes* mosquitoes eradicated based on the overall egg counts of 22,891 and 26,259 eggs in Village 1 (Moo.2) and Village 2 (Moo.10), respectively. However, when comparing egg quantities for each month and between villages, both indoors and outdoors, it was noted that in 2021, July had a higher number of eggs than August, and this disparity was found to be statistically significant ($p < 0.05$) (Table 2).

Table 3 clearly shows that among a total of 1,024 LeO-Traps in Village 1 (Moo.2), 590 were identified as positive for containing eggs, leading to a rate of 57.52%. On the other hand, 716 of 1,076 LeO-Traps in Village 2 (Moo.10) showed positive results at a notably higher rate of 69.12%. When the quantity of *Aedes* mosquito eggs was compared across each village, the findings indicated no statistically significant difference in both July and August ($p \geq 0.05$) (Table 2). Based on the comparison of dengue fever patient reports between two villages located in the Don-Kaew sub-district of Mae Rim district, Chiang Mai, Thailand, from 2016 to 2020, it was found that the number of dengue fever cases tended to decrease in 2018. No dengue fever patients were reported in Village 1, and the morbidity rate was 123.6 per hundred thousand population in Village 2. However, there was a trend of increasing dengue fever cases in 2019-2020, with morbidity rates of 73.3-108.3 per hundred thousand population in Village 1 and 504.4-503.1 per hundred thousand population in Village 2 (Figure 1).

Furthermore, climatic conditions are an additional critical factor influencing the management of dengue fever, particularly the frequency of rainfall. Rainwater has the potential to accumulate in various environments, such as containers, thus creating breeding sites for mosquitoes. The Chiang Mai Meteorological Station recorded rainfall of 135 and 102 milliliters in July and August 2021, respectively (Figure 2).

Table 1 The prevalence index of mosquito vector eggs for each month in 2021.

Village	No. of houses	Ovitrap Index (OI)		House Index (HI)	
		July	August	July	August
Village 1 (Moo.2)	129	70.54	44.49	89.15	58.13
Village 2 (Moo.10)	166	80.10	70.31	94.17	78.31

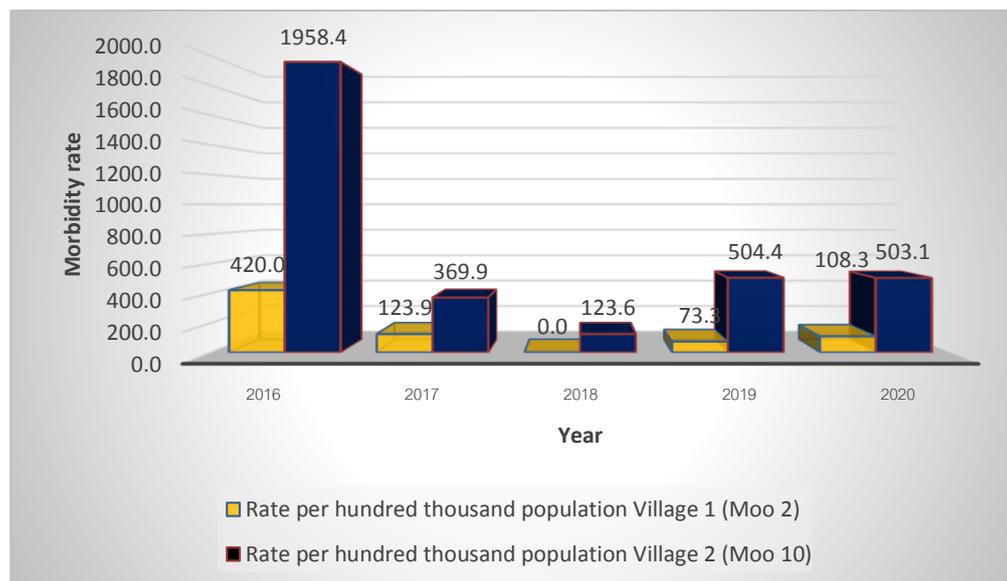
Table 2 Number of eggs in LeO-Traps for each month, divided by village in 2021.

Village	Number of eggs (July 2021)				Number of eggs (August 2021)			
	Indoor (SE)	Outdoor (SE)	Total	p-value*	Indoor (SE)	Outdoor (SE)	Total	p-value*
1	7,627 (87.84)	7,535 (130.57)	15,254	0.95	4,069 (67.87)	3,568 (52.06)	7,637	0.07
2	6,087 (87.28)	8,497 (93.99)	14,584	0.15	4,897 (47.31)	6,778 (65.75)	11,675	0.08
Village	Indoor				Outdoor			
	July (SE)	August (SE)	Total	p-value*	July (SE)	August (SE)	Total	p-value*
1	7,627 (87.84)	4,069 (67.87)	11,696	0.01	7,535 (130.57)	3,568 (52.06)	11,103	0.03
2	6,087 (87.28)	4,897 (47.31)	10,984	0.00	8,497 (93.99)	6,778 (65.75)	15,275	0.00
Total	13,714	8,966			16,032	10,346		
p-value*	0.89	0.06			0.57	0.10		

*The level of significance $\alpha = 0.05$, *SE: Standard error of the mean.

Table 3 Monthly frequency of Aedes egg discovery in LeO-Traps categorized by village in 2021.

Village	Indoor			Outdoor			Total		
	No. of traps	Traps containing eggs (Trap)	Trap containing eggs (%)	No. of traps	Traps containing eggs (Trap)	Trap containing eggs (%)	No. of traps	Traps containing eggs (Trap)	Trap containing eggs (%)
Village 1									
July	258	192	74.42	258	172	66.67	516	364	70.54
August	254	132	51.97	254	94	37.01	508	226	44.49
Total							1,024	590	57.52
Village 2									
July	206	152	73.79	206	178	86.41	412	330	80.10
August	332	192	57.83	332	194	58.43	664	386	58.13
Total							1,076	716	69.12

**Figure 1** Number of dengue patients within two villages located in the Don-Kaew sub-district of Mae Rim district, Chiang Mai, Thailand.

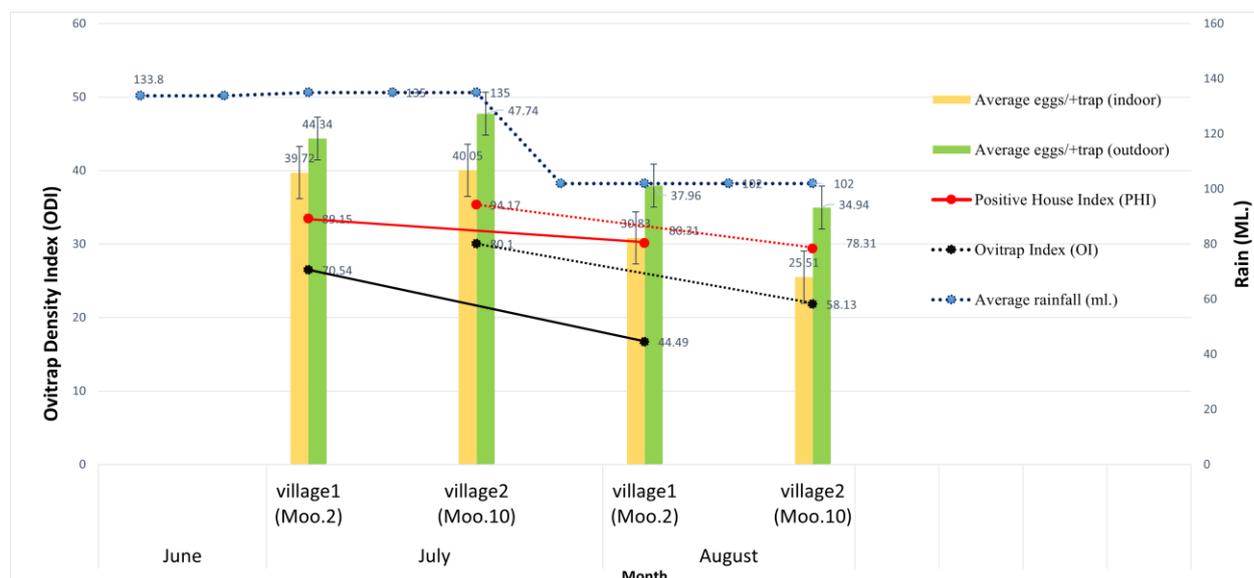


Figure 2 Correlation between the *Aedes* larval prevalence index (measured by OI and HI) and average monthly rainfall in each village.

Discussion

This study showed that LeO-Traps successfully collected 22,891 and 26,259 eggs in Village 1 (Moo.2) and Village 2 (Moo.10), respectively. Consequently, this approach has the potential to decrease a mosquito population of around 12,287,500 adults within a 2-month period. In both villages, OI and HI indices exhibited a significant decrease during July and August 2021. Furthermore, there was no statistically significant difference in the number of mosquito populations between indoor and outdoor environments. As a result, human individuals face an equivalent probability of contracting dengue in both locations. However, earlier research indicated statistically significant differences in the quantity of *Aedes* eggs between indoor and outdoor environments (Sapcharoen *et al.* 2021). This depends on controlling methods and mosquito behaviors in each area. In general, *Ae. aegypti* mosquitoes are active during the daytime and prefer to lay their eggs in stagnant water within various household containers such as cabinet legs, saucers, water containers, etc., while *Ae. albopictus* are active primarily during the daytime, much like *Ae. aegypti* mosquitoes, but are commonly located in outdoor environments like gardens. Furthermore, climate is another critical factor influencing *Aedes* mosquito populations, as it directly impacts their life cycle progression. In this study, the average rainfall data were provided by Chiang Mai Meteorological Station, indicating 135 and 102 milliliters of rain for July and August 2021, respectively. As a result, there has been a significant decline in mosquito populations. This highlights that rainfall plays a vital role in the emergence of dengue fever outbreaks in Thailand (Thavara *et al.*, 2015). The study by Wee *et al.* (2013) acknowledged that rainfall is a key environmental factor linked to *Aedes* breeding in the study areas. However, the reduction in the mosquito population still depends on the use of the Leo-Trap, consistent with the findings of Molitto *et al.* (2020).

One of the fundamental strategies employed for preventing and managing Dengue fever involves the

surveillance and control of *Aedes* mosquito vectors. Decreasing the number of mosquito eggs disrupts the life cycle of these mosquitoes during their vulnerable early stages of breeding. This approach proves valuable in curbing the transmission of communicable diseases carried by *Aedes* mosquitoes, particularly if the *Aedes* eggs are harboring the virus. Previous research revealed that *Ae. aegypti* exhibits a higher rate of dengue infection compared to *Ae. albopictus* (Thavara *et al.*, 2015). In terms of control methods, LeO-Traps is asserted to be the most efficient approach when compared to visual larval surveys and adult surveys conducted using sweep nets (Sevana *et al.*, 2021).

Based on the outcomes of this investigation, it was discovered that LeO-Traps can reduce mosquito populations. They can efficiently attract female mosquitoes from both *Ae. aegypti* and *Ae. albopictus* species for the purpose of egg-laying (Tawatsin *et al.*, 2019). Molitto *et al.* (2020) employed LeO-Traps to decrease the population density of *Aedes* mosquitoes in areas of Songkhla province when facing dengue outbreaks. Moreover, Sapcharoen *et al.* (2021) revealed that LeO-Trap zeolite granules appear to be a viable method for eradicating *Aedes* mosquito larvae in Trang province. This approach holds the potential for an added vector control strategy. In conclusion, the LeO-Trap is an innovative device that offers both economic and environmental benefits by effectively controlling populations of *Ae. aegypti* and *Ae. albopictus* mosquitoes.

Acknowledgments

This study received support from the National Research Council of Thailand (Grant No. NRCT5-RSA63001-03) and the Department of Medical Sciences, Ministry of Public Health, Thailand. Additionally, the authors extend their gratitude to the Regional Medical Sciences Center 1, Chiang Mai, and the dedicated volunteer staff from Don-Kaew Subdistrict Health Promotion Hospital who participated in the field surveys and data collection.

Ethical approval: All procedures involving animals were reviewed and approved by the Institutional Animal Care and Use Committee of the [Faculty of Medicine, Chulalongkorn University] (IACUC protocol number: 025/2564).

References

- Barrera R, Amador M, Acevedo V, Caban B, Felix G and Mackay AJ 2014. Use of the CDC autocidal gravid ovitrap to control and prevent outbreaks of *Aedes aegypti* (Diptera: Culicidae). *J Med Entomol.* 51(1): 145-154.
- Brown AWA 1973. Surveillance system for *Aedes aegypti* and related stegomyia mosquitoes in terms of density. WHO/VBC/73. 464, 32 pp.
- Brown M and Hebert AA 1997. Insect repellents: An overview. *J Am Acad Dermatol.* 36: 243-249. doi.org/10.1016/S0190-9622(97)70289-5.
- Chareonviriyaphap T, Bangs MJ, Suwonkerd W, Kongmee M, Corbel V and Ngoen-Klan R 2013. Review of insecticide resistance and behavioral avoidance of vectors of human diseases in Thailand. *Parasit Vectors.* 6: 280.
- Department of Disease Control 2020. The situation of mosquito-borne diseases and the risk assessment for outbreaks in 2021. <https://ddc.moph.go.th/uploads/publish/1212820211229113331.pdf>.
- Department of Disease Control 2023. The situation of communicable diseases transmitted by insects. Available: <https://ddc.moph.go.th/dvb/pagecontent.php?page=1269&dept=dvb>.
- Department of Medical Sciences 2021. Prevention and control of *Aedes* mosquitoes, the cause of dengue fever, chikungunya, and Zika virus. <https://www.youtube.com/watch?v=yYfQe-AXGHs>.
- Hodgson RW 1967. The citrus industry. In: Horticultural Varieties of Citrus. University of California Press. Berkeley, CA, USA.
- Johnson BJ, Ritchie SA and Fonseca DM 2017. The state of the art of lethal oviposition trap-based mass interventions for arboviral control. *Insects.* 8(1): E5.
- Mehlhorn H, Zhongdao W and Ye B 2014. Treatment of Human Parasitosis in Traditional Chinese Medicine. Springer-Verlag. Berlin, Germany.
- Ministry of Public Health 2017. Annual Epidemiology Surveillance Report 2017. <https://apps.doe.moph.go.th/boeeng/download/AESR6112-24.pdf> [in Thai].
- Molitto C, Thammapalo S, Moonmek S, Saowarun T and Uppapong B 2020. Application of LeO-Trap on Reduction of *Aedes* Mosquitoes in Dengue Endemic Areas, Songkhla Province. *Bull Dept Med Sci.* 62 (1): 6-15.
- Office of Dengue Control, Department of Disease Control, Ministry of Public Health 2002. Dengue Fever: Edition of the Ministry of Public Health. 2nd Edition. Bangkok: Cooperative Farming of Thailand Printing House.
- Parker CN, Pereira RM, Baldwin RW, Chaskopoulou A and Koehler PG 2017. Laboratory evaluation of a novel lethal ovitrap for control of *Aedes aegypti*. *J Med Entomol.* 54(6): 1666-1673.
- Pujol JL 2011. The importance of biological interactions in the study of biodiversity. InTech, Winchester, UK.
- Qiu H, Jun HW and McCall JW 1998. Pharmacokinetics, formulation, and safety of insect repellent N, N-diethyl-3-methylbenzamide (deet): A review. *J Am Mosq Control Assoc.* 14: 12-27.
- Rivero A, Vezilier J, Weill M, Read AF and Gandon S 2010. Insecticide control of vector-borne diseases: when is insecticide resistance a problem?. *PLoS Pathog.* Available: <http://dx.doi.org/10.1371/journal.ppat.1001000> e1001000.
- Roberts DR and Andre RG 1994. Insecticide resistance issues in vector borne disease control. *Am J Trop Med Hyg.* 50: 21-34. doi.10.4269/ajtmh.1994.50.21.
- Sapcharoen S, Kanin C, Thepmaneerat W, Krausit K, Baikodem J and Ruchusatsawat K 2021. Integrated prevention and control of dengue haemorrhagic fever vectors in high risk areas in Trang. *Bull Dept Med Sci.* 63(1): 107-118.
- Somboon P, Prapanthadara L and Suwonkerd W 2003. Insecticide susceptibility tests of *Anopheles minimus*, *Aedes aegypti*, *Aedes albopictus* and *Culex quinquefasciatus* in northern Thailand. *Southeast Asian J Trop Med Public Health.* 34: 87-93.
- Tawatsin A, Thavara U, Srivarom N, Siriyasatien P and Wongtitiro A 2019. LeO-Trap®: a novel lethal ovitrap developed from combination of the physically attractive design of the ovitrap with biochemical attractant and larvicide for controlling *Aedes aegypti* (L.) and *A. albopictus* (Skuse) (Diptera: Culicidae). *Biomed J Sci Tech Res.* 21(5): 16183-92.
- Thavara U, Bhakdeenuan P, Thawatsin A, Chompoosri J, Khumsawads C, Phusup Y, Phumee A, Pengsakul T, Siriyasatien P and Sangkitporn S 2015. Biology of dengue vectors and serotypes of dengue virus in infectious cycle in Thailand. *Bull Dept Med Sci.* 57(2): 186-96.
- Thanispong K, Achee NL, Grieco JP, Bangs MJ, Suwonkerd W, Prabaripai A, Chauhan KR and Chareonviriyaphap T 2010. A high throughput screening system for determining the three actions of insecticides against *Aedes aegypti* (Diptera: Culicidae) populations in Thailand. *J Med Entomol.* 47: 833-841.
- Thavara U, Tawatsin A and Chompoosri J 2004. Evaluation of attractants and egg-laying substrate preference for oviposition by *Aedes albopictus* (Diptera: Culicidae). *J Vector Ecol.* 29(1): 66-72.
- Wee LK, Weng SN, Raduan N, Wah SK, Ming WH, Shi CH, Rambli F, Ahok CJ, Marlina S, Ahmad NW, Mckemy A, Vasan SS and Lim LH 2013. Relationship between rainfall and *Aedes* larval population at two insular sites in Pulau Ketam, Selangor, Malaysia. *Southeast Asian J Trop Med Public Health.* 44(2): 157-66.
- Williams CR, Long SA, Russell RC and Ritchie SA 2006. Optimizing ovitrap use for *Aedes aegypti* in Cairns, Queensland, Australia: Effects of some abiotic factors on field efficacy. *J Am Mosq Control Assoc.* 22(4): 635-640.

- Williams CR, Ritchie SA, Long SA, Dennison N and Russell RC 2007. Impact of a bifenthrin-treated lethal ovitrap on *Aedes aegypti* oviposition and mortality in north Queensland, Australia. J Med Entomol. 44(2): 256-262.
- World Health Organization 2012. Global strategy for dengue prevention and control 2012-2020. World Health Organization. <https://apps.who.int/iris/handle/10665/75303>.
- Zeichner BC and Perich MJ 1999. Laboratory testing of a lethal ovitrap for *Aedes aegypti*. Med Vet Entomol. 13(3): 234-238.