ORIGINAL ARTICLE

Association of Temperature and Rainfall with *Aedes* Mosquito Population in 17th College of Universiti Putra Malaysia

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ABSTRACT

Introduction: Dengue is an arboviral disease affecting many tropical and subtropical regions. Statistics in Malaysia show that a cumulative of 57,627 number of DF cases with 94 cumulative number of deaths have occurred until July 8th 2020. Weather affects *Aedes* mosquito population and dengue incidence through the breeding behaviour of mosquitoes. This study aims to evaluate the association of temperature and rainfall with *Aedes* mosquito population in the 17th College, Universiti Putra Malaysia (UPM) and also to evaluate the accuracy of mobile 'AedesTech' automated counting application. **Methods:** *Aedes* Mosquito Home system (AMHS) were placed at each level of Block A, B, C and D of 17th College, UPM. The eggs laid by *Aedes* mosquito on the tissues inside the ovitrap were counted manually and via 'AedesTech' automated counting application. Monthly temperature and rainfall data from November 2018 until April 2019 were obtained from Malaysian Meteorological Department. **Results:** Temperature was inversely correlated to *Aedes* mosquito eggs count and ovitrap index. Rainfall was directly correlated to *Aedes* population as the number of mosquito eggs and ovitrap index were high in months recording high rainfall. The number of eggs count from 'AedesTech' Mobile App Version 5.9 (M=143) was significantly higher than the numbers from manual counting (M=35) indicating the 'AedesTech' auto-count is inaccurate. **Conclusion:** Temperature and rainfall have an influence on the *Aedes* mosquito population in the 17th College, UPM. The 'AedesTech' Mobile App Version 5.9 has low accuracy and therefore needs to be upgraded.

Keywords: *Aedes* mosquito, Dengue, Temperature, Rainfall, Vandalism

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INTRODUCTION

Dengue fever (DF) is an infectious tropical disease caused by dengue virus. DF is an acute febrile disease transmitted by *Aedes* mosquitoes specifically *Aedes aegypti* (Linnaeus) and *Aedes albopictus* (Skuse) (1). Four different dengue virus strains identified to date; DENV-1, DENV-2, DENV-3 and DENV-4 (2), apparently circulate among Malaysians. DENV-1, DENV-2 and DENV-3 were identified in Negeri Sembilan (3), multiple entries of DENV-2 and DENV-4 in Sarawak (4) while the populated regions of Kuala Lumpur and Selangor have been dominated by DENV-4 (5). In most cases, humans are the main host (6), whereas monkeys act as a reservoir host in West Africa and South-East Asia (7).

Dengue virus is currently the most common cause of arboviral disease worldwide. Even though 129 countries have continuous and frequent dengue cases reported, 70% of the actual burden of dengue infection is in Asia (8). WHO recorded over 8 fold increase worldwide over the last twenty years from 505,430 cases in 2000, to more than 2.4 million in 2010, and 4.2 million in 2019 (9). In Malaysia, a total number of 130,101 DF cases were recorded in 2019 with 182 dengue-related deaths while a cumulative of 57,627 number of DF cases with 94 cumulative number of deaths have occurred until July 8th, 2020 (10). Universiti Putra Malaysia (UPM), a public university in Malaysia has been recording high number of DF cases for many years. Records from the Health Centre of UPM showed that 43% of the students who received medical treatment for DF until November 2013 were from the 17th residential College (6).

Adult *Ae. aegypti* and *Ae. albopictus* are active both indoors and outdoors. They are not long-distance fliers and hence only move within a close vicinity throughout their lifetime. Both *Aedes* species prefer biting after sunrise and before sunset (11). Due to their broad geographic ranges, the population of *Ae. aegypti* and *Ae. albopictus* are largely determined by environmental factors. Temperature and rainfall at a particular region have a well-defined influence on the mosquito's population (12-15). In addition, the dynamics of the *Aedes* population is impacted by environmental abiotic factors, size and location of water bodies, climate, water's physical and chemical properties and distance from human (16). These parameters are in fact used as reference to forecast possible dengue incidence or outbreak (17).

Peninsula Malaysia's climatic trend is characterised into four seasons which includes two monsoon and two inter-monsoon seasons (18-19). The northeast monsoon season that occurs from November to February is followed by one inter-monsoon season between March and April. On the other hand, the southwest monsoon seasons occurs from May to August and is tail-ended with another inter-monsoon season between October and November (18-19). Convective rain causes heavy rainfall during the inter-monsoon season where the west coast is mostly wetter than the east coast (18). This study was carried out in Selangor which is located at the west coast of the Peninsula. The study period from November to April included part of two inter-monsoon seasons and the northeast monsoon season. Based on our previous research, we found that the 17th College of UPM has high population of both *Ae. aegypti* and *Ae. albopictus* (20). However, the seasonal pattern of mosquito population in the vicinity of 17th College of UPM has not been reported.

In the effort to monitor *Aedes* mosquito population and to predict possible outbreaks, statistics and information are constantly collected by the Vector Control Unit of the Ministry of Health. The collected information is used to develop appropriate vector control actions and programs in reducing *Aedes* mosquito transmission. The number of *Aedes* mosquito eggs in the ovitraps are usually counted manually, which could be laborious and less accurate due to possible human error. Therefore, we have introduced an automated counting technology, 'AedesTech' Mobile App Version 5.9 to overcome the existing drawbacks.

This study aims to evaluate the mosquito population relative to temperature and rainfall in the 17th College of UPM. Furthermore, this study also assessed the accuracy of the 'AedesTech' Mobile App Version 5.9 automated counting application.

MATERIALS AND METHODS

Study Location

We carried out this study at the 17th College of UPM which was situated adjacent to Hospital Pengajar UPM and Hospital Serdang, Selangor (Coordinates: 2.9766° N, 101.7174° E). The college comprises of four residential blocks namely Blocks A, B, C and D which includes four wings with five levels at each block. Forest and small ponds were situated lesser than 500 m and 100 m, respectively from the residential blocks.

Temperature and Rainfall

The effect of temperature and rainfall on the *Aedes* mosquito population is a descriptive study as we observed the existing natural phenomena such as temperature, rainfall and *Aedes* population without any interventions from the researchers. We obtained daily temperature and rainfall data from November 2018 until April 2019 from the Malaysian Meteorological Department station in Petaling Jaya which was situated 16 km from our study area.

Ovitrap Instalment

Commercial mosquito trap, *Aedes* Mosquito Home system, AMHS (Fig. 1A) with an opening diameter of 14.0 cm, base diameter of 10.8 cm and height of 17.0 cm; black container and purple cover was provided by One Team Network Sdn. Bhd. Non-woven tissues (17.5 cm x 7.3 cm) that served as substrate for the *Aedes* mosquitoes to oviposit were placed in the AMHS. We filled approximately 20 mL of chemical attractant (Lim Chee Hwa, personal communication April 29, 2018) (20) into the trap to attract female mosquitoes and replaced the solution every 6-8 weeks depending on the rate of evaporation.

We deployed forty AMHS at each block with a total of 160 ovitraps for the entire college. One AMHS was fixed at each set of staircases as shown in Fig. 1C and

Figure 1: (A) *Aedes* Mosquito Home system (B) Image of eggs captured at a fixed distance before counting using 'AedesTech' Mobile App Version 5.9 (C) one AMHS fixed at each flight of stairs for *Aedes* mosquito egg collection.

each floor has two flights of staircases leading to the next level. We secured AMHS to the stair's railing with Hellermann Tyton White Nylon Cable Tie, 200 mm x 4.6 mm. We collected and air-dried the wet non-woven tissue inside the AMHS on a monthly basis and new ones were placed for the next collection (20).

Aedes Mosquito Eggs Counting

The method to determine the accuracy of the 'AedesTech' Mobile App is a Diagnostic, Validity or Reliability Study whereby the sensitivity and specificity of this tool was used to measure variables.

Automated Counting

'AedesTech' Mobile App Version 5.9 was developed by a team from the Universiti Malaysia Terengganu (UMT). By cropping a digitalized image at the desired area on the tissue attached, the *Aedes* mosquito eggs were counted. The automated counting technology from this mobile application also enabled users to track the location of the ovitraps via QR codes.

First, we captured the parallel-to-the-plane image of the air-dried tissue as shown in Fig. 1B. The application then digitalized the images, identified the eggs, automatically counted them and recorded the data to the cloud.

Manual Counting

We then subjected the same tissues with *Aedes* mosquito eggs to manual counting under a magnifying glass. The eggs were identified as singly, long, smooth, ovoid shaped, of approximately one millimetre long black structures (21) and the counts were recorded.

Data analysis

We analysed the data using Statistical Package for Social Science (SPSS) version 25. Pearson's Correlation test was used to evaluate the association of temperature and rainfall with *Aedes* mosquito population. The Ovitrap Index (OI) was calculated using the following formula:

$$\text{Ovitrap Index, OI} = \frac{\text{No.of positif ovitraps (with eggs)}}{\text{No. of ovitrap deployed}} \times 100\%$$

Data were analysed using Wilcoxon Signed-Rank test to determine the similarity of automated and manual mosquito eggs counting.

RESULTS

We determined the OI by the mean number of eggs per ovitrap (as counted in the manual counting) placed in the 17th College, UPM. The OI ranging from 31.9% to 74.3% was the highest in November 2018 and lowest in the month of January 2019 (Fig. 2). A total of 21,402 *Aedes* mosquito eggs were collected in 17th College, UPM throughout the six months where the highest number were recorded in November 2018 with 6,703 eggs, whereas the lowest was in January 2019 with 2,258 eggs. Both the OI and number of eggs collected have the similar general pattern where the highest values were observed in the month of November, after which there was a drastic reduction in December and January, before it increased in the months of February and April. A high correlation was shown between OI and the mean number of mosquito eggs at a value of r = 0.935.

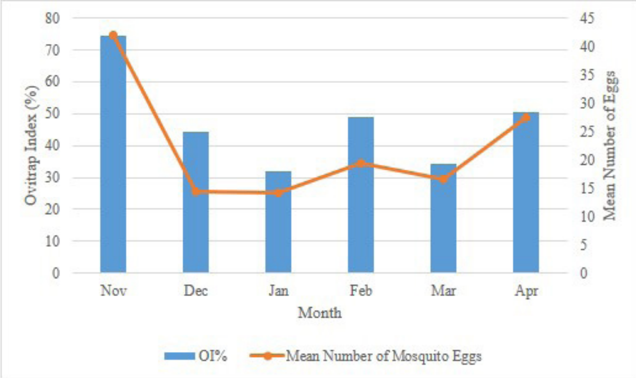

Figure 2: Correlation between Ovitrap Index and mean number of *Aedes* mosquito eggs collected in 17th College, UPM

The correlation between OI and temperature in 17th College, UPM is depicted in Fig. 3A. Temperature was low in November 2018, decreased further in December 2018, and gradually increased until March 2019, before it decreased in April 2019. When the temperature dropped, the ovitraps positive with mosquito eggs increased. The OI and temperature exhibited inverse correlation at a value of r = -0.551. Fig. 3B presented the correlation between total mosquito eggs collected and temperature. This generally showed a trend of an increased total number of mosquito eggs when the temperature reduces indicating an inverse correlation, r = -0.341 between the parameters.

The correlation between OI and rainfall in the 17th College, UPM is depicted in Fig. 4A. The rainfall was high in November 2018, decreased until February 2019, before it increased again in the months of March and April 2019. As the rainfall increased, the number of ovitraps positive with mosquito eggs also increased. The correlation of OI and rainfall is r = 0.690 which indicated both parameters were positively correlated. A similar trend was shown in Fig. 4B indicating that when rainfall increased, the number of total mosquito eggs also increased. This showed high correlation between the mean number of the total mosquito eggs and rainfall, r = 0.752.

The comparison between manual counting and automated counting of *Aedes* mosquito eggs was shown in Fig. 5. The median number of eggs obtained from the automated counting have significant difference ($p < 0.05$) with the values of manual counting. The number of *Aedes* mosquito eggs was lower in manual counting compared to automated counting.

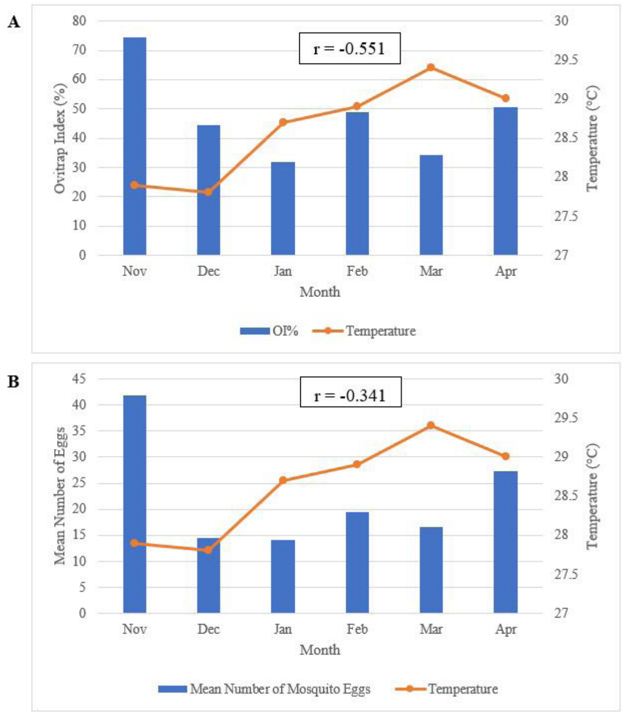

Figure 3: Correlation between (A) ovitraps index (B) mean number of mosquito eggs, and temperature in 17th College, UPM

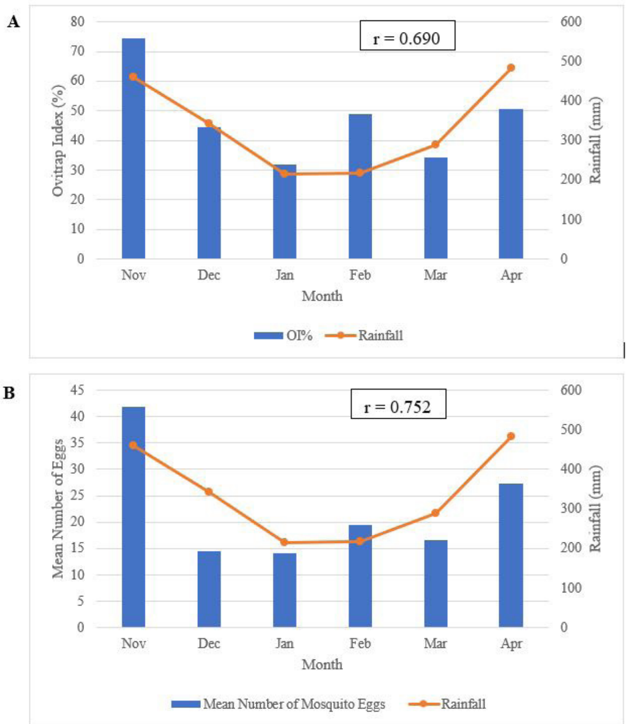

Figure 4: Correlation between (A) ovitraps index (B) mean number of mosquito eggs, and rainfall in 17th College, UPM

The *Aedes* mosquito eggs attached on the non-woven tissue are characterized as singly and black in colour (Fig. 6A). The expected digitalised image of the *Aedes* mosquito eggs before it is quantified by the 'AedesTech' Mobile App Version 5.9 is depicted in Fig. 6B. The red dots represented the detected *Aedes* mosquito eggs. The

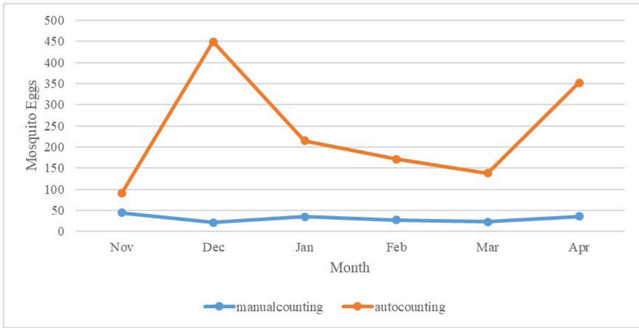

Figure 5: Median values of mosquito eggs counted manually in comparison to automatic counting

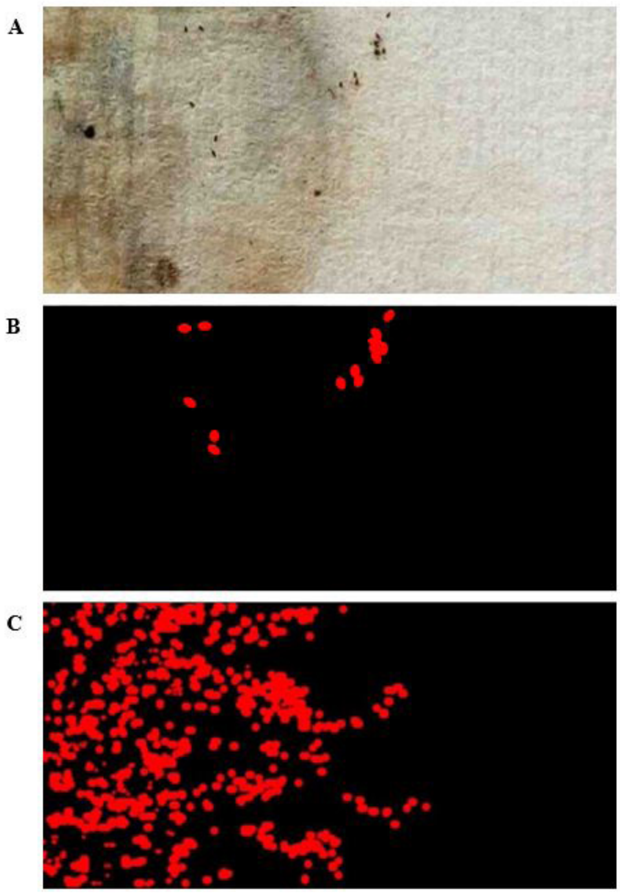

Figure 6: Image analysis of tissue attached *Aedes* mosquito eggs. The eggs appear singly and black in colour. (A) expected automated counting read (B) actual interpretation of automated eggs counting by 'AedesTech' Mobile App Version 5.9

digitalised image (Fig. 6C) obtained from the 'AedesTech' mobile application showed that some background noises were falsely detected as mosquito eggs.

The differences in the manual counting and automated counting values of *Aedes* mosquito eggs was represented in Table I. The manual counting of *Aedes* mosquito eggs was statistically different ($p < 0.05$) from 'AedesTech' Mobile App Version 5.9. A total of 455 samples were screened and compared between the automated and manual counting. Only four tissue sample readings

Table I: Ranks of Wilcoxon's signed-rank test for manual and automated counting

Ranks	Number of samples
Automated < Manual	85
Automated > Manual	366
Ties	4
TOTAL	455

matched or showed equal counts between the two modes of counting. The automatic counting recorded much higher values compared to the actual (manual count) in 85 samples and showed vastly lower values in 366 samples.

DISCUSSION

In this study, the meteorological parameters such as rainfall and temperature have an effect on the mosquito population in 17th College, UPM. *Aedes* mosquito species colonize the tropical and sub-tropical regions, particularly in residential area that provides good habitats for breeding. They prefer to breed in clean and stagnant water which could be easily found in containers or objects that could accumulate water (22). The concrete drainages around the vicinity of 17th College, UPM hold clear stagnant water, providing potential breeding sites for these mosquitoes. According to Chen et al. (23), clean residential environment with no water storage, is still prone to recording high *Aedes* mosquito population as concrete drainage system outside the houses are possible breeding habitats.

The mosquito population was inversely associated to the temperature as we observed lower density of mosquito eggs during higher temperature (28.9-29.4°C). The low number of mosquito eggs along with high temperature was probably because of shortage of breeding sites as many small water bodies would be dried up. Furthermore, the study area which is an urban area provides fewer ideal breeding conditions due to low humidity and limited vegetations compared to rural areas (24).

Cheong et al (25) reported that *Aedes* mosquitoes have higher oviposition activities during warmer climates due to frequent and efficient feeding and digestion activities. In addition, the survival temperature of *Aedes* mosquito species ranges from 15°C to 35°C (26-28), perfectly falls in the Malaysian temperature which ranges from 21°C to 32°C (29). An increase from 25.4°C to 26.5°C sees a 11.92% increased relative risk of dengue cases (25). However, this was not reflected in this study. The high temperature in our study is reported to be 28.7°C and 29.3°C which probably is a harsher environment for the *Aedes* mosquitoes. This external condition was probably unfavourable for the mosquitoes whereby the ingested blood is prioritised for the female's survival rather than their fecundity during this period (30-31). In addition, high temperature could result in adult dehydration lowering their survival and the insect's population size (26). Furthermore, temperature plays a predominant role in the length of the life cycle development, vector's survival rates, dengue virus incubation period as well as the virus transmission cycle (13-15).

We observed a linear relationship between rainfall and mosquito population whereby higher count of mosquito eggs were recorded in months with higher rainfall. This outcome is in line with the studies carried out in Puerto Rico, Mexico, and Thailand (32), Brazil (33), Malaysia (25,34) and Manila (35). Rainfall provides many breeding sites for *Aedes* mosquitoes ovipositing activities and aquatic population which includes the eggs, larvae and pupae (36-37). Water storage containers such as barrels, concreate tanks, buckets, plastic tanks, plastic bottles and containers not intended for water storage such as discarded articles, tyres, plants, leaf axils and flower pots that are filled with water either manually or following a downpour are the vectors primary breeding sites (38). The absence of rainfall does not provide breeding site sources to oviposit (39). However, excessive rainfall causes overflowing of breeding sites washing away the larvae of the mosquitoes leading to significant mortality of larvae (40). Heavy rainfall accompanied by strong winds can cause difficulties in flight activity of the *Aedes* mosquito to other possible breeding sites, reducing their oviposition behaviour (41).

In this study we also evaluated the mobile application 'AedesTech' which used an image processing approach. The application would digitalize the images before detecting the counts. It was invented to overcome the limitations of manual counting which are time-consuming, laborious and prone to human errors (42).

The mosquito eggs image processed by the 'AedesTech' Mobile App Version 5.9 was not clear and therefore, many details were missed out leading to inaccurate detection. This version of the application was not able to distinguish mosquito eggs and the background or other foreign structures that might be present on the tissue. The presence of fungus at the background due to the moist environment inside the closed ovitraps, interfered with the count as the automated detection falsely counted the fungus as mosquito eggs. The technology of 'AedesTech' Mobile App Version 5.9 needs improvisation specifically in terms of sensitivity and accuracy to improve the overall system performance as this mobile application is still at the initial stage of trial.

CONCLUSION

Temperature and rainfall influence the *Aedes* mosquito population in 17th College, UPM. The *Aedes* mosquito population was higher during lower temperature (27.8-27.9°C) and higher rainfall (482.8–460.0 mm). The

'AedesTech' Mobile App Version 5.9 has low accuracy and therefore, requires optimisation and upgrading in the form of sensitivity and accuracy.

ACKNOWLEDGEMENTS

The authors thank Mr. Lim Chee Hwa from One Team Network Sdn. Bhd. for his kind contribution in providing financial assistance, AMHS and other necessary materials for this project. The authors are also grateful to Malaysian Meteorological Department for providing this study with the data on temperature and rainfall. Special thanks to the17th College UPM, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia for providing the facilities.

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