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Abstract: Temperature is the main environmental factor affecting the growth of the mosquito population. It is important to study the effect of temperature on the life parameters of *Aedes albopictus* and *Aedes aegypti* in the local environment. This will subsequently provide an in-depth understanding on the biology of *Aedes* mosquitoes which will eventually affect the transmission of dengue viruses directly to human. This study examined the effect of constant temperatures on the developmental period of both local *Aedes* species strains using environmental chambers. Artificial and natural containers were used to examine the association of the types of containers to the development of both *Aedes* species. It was found that the increase in temperature may reduced the developmental period of the mosquito. In terms of the types of breeding containers, shortest development was recorded in the coconut shells, followed by tires, glass jars and plastic cups for both *Aedes* species. These findings provided valuable baseline information on the potential effects of climate change on the bionomics of *Aedes* mosquitoes and its density towards an improve vector control.

Keywords: temperature; climate; *Aedes*; *albopictus*; *aegypti*; development; survival; humidity; breeding container.

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1 Introduction

Dengue has now emerged and persistent as one of the significant public health problems in Malaysia. The alarming rise of dengue epidemiology has been highlighted to haunt 40% of the world population; where disease severity varies from asymptomatic infection to undifferentiated dengue fever (DF) or possible develop into life-threatening manifestations such as dengue haemorrhagic fever (DHF) and dengue shock syndrome (DSS) (Murrell et al., 2011). Urbanisation, demographic and environmental factors strongly influence the global distribution of dengue disease.

The leading cause of DF is *Aedes* mosquito. People who live near to the mosquito breeding area are likely to get the fever. The *Aedes* mosquito breeds only in stagnant water, which usually found in the residential sector (Othman and Danuri, 2016). New housing and old residential places are two main areas where *Aedes* mosquitoes prefer to breed (Seng et al., 2005; Shaharudin et al., 2002). Transmission cycles of DENV are observed from two phenomena:

1 sylvatic cycle of canopy-dwelling *Aedes* mosquitoes that infect non-human primates in rainforest habitats of Asia and Africa

2 infection of human hosts by *Ae. aegypti* (primary vector) and/or *Ae. albopictus* that circulate in urban and peri-urban environments of tropics (Medeiros et al., 2018).

Changes in climate factors such as temperature rising, increased rainfall and relative humidity are the most influential driving forces of dengue transmission and intensity in Malaysia (Ambu et al., 2002; Ismail et al., 2010). A recent study by Phanitchat et al. (2017) has resulted that *Aedes albopictus* underwent rapid development at a high temperature while conversely; the survival rate was highest at an average temperature and lowest at a high temperature.

During Malaysia's rapid industrialisation and economic growth in the past several decades, massive infrastructure development resulted the spread of the disease (Kwa, 2008; Alam, 2013; Juanarita et al., 2012). The study also reported that the continuous process of urbanisation has resulted in an increased incidence of dengue in Malaysia. A recent study reveals that dengue has spread from urban city centres to the more rural populations of Malaysia, including to the forest fringe areas where the majority of the aboriginal communities resides (Abd-Jamil et al., 2014).

As stated by Nur Aida et al. (2011), the information related to the survivorship and fecundity of the mosquito is critical to the transmission of diseases. As dengue cases keep increasing in Malaysia, quantifying the embryo's survivorship may help in providing crucial information on the population persistence. Dieng et al. (2010) found that *Ae. albopictus* is now breeding near to human residential area, therefore this study is essential to predict the *Aedes* species population size in relation to temperature effect and knowing their population dynamics of mosquitoes may assist in the preliminary and a rudimentary indication of the population status (Nur Aida et al., 2011).

According to the aim of our research, we, firstly, measuring the microclimate between the indoor and outdoor (I/O) of the study location. Then, we assess the development cycles of immatures of *Aedes albopictus* at the different water temperatures and water containers in a controlled environment. Finally, the rates of development between the aquatic stages were compared between *Ae. albopictus* and *Ae. aegypti*.

2 Theoretical background: development of immature *Aedes* spp.

The dynamics of dengue transmission are influenced by multiple complex risk factors including population movement, dengue control capacity, weather or climate, circulation of DENV, the role of vector and immunity of host. The changes in global temperature, precipitation and humidity that are expected to occur due to projected climate change will affect the biology and ecology of disease vectors and consequently the risk of vector-borne disease transmission (Gubler et al., 2001; Tong et al., 2008; Shuman, 2011). Environmental factors strongly influence the lifecycle and vectorial capacity of *Ae. aegypti* and *Ae. albopictus*. For example, temperature affects adult longevity, immature development, extrinsic incubation period (EIP), and other components of *Aedes* life history and vectorial capacity (Simoy et al., 2015; Tjaden et al., 2013; Mordecai et al., 2017). The association of temperature with adult survival frequently features in *Aedes* population and diseases models (Yang et al., 2011).

In the early set of experiments, Goindin et al. (2015) found out that the expectation of life varies with the parity rates and according to the temperatures, with the durations from about ten days at low parity rates at the higher temperature to an optimal duration of about 35 days when 70% of females are parous at 27°C. In the lower parous rates, the infective life expectancy was found highly variable and again the optimal durations were found when more than 50% of females are parous for the mean temperature of 27°C and 30°C. Lopes et al. (2014) conducted the study in two different season which is during winter and spring season when positioned inside (peri) and outside (intra) a laboratory. Outcome of the study is that larvae placed in the intra resulted in the lowest median time to develop in the individual and collective experiment (9 and 10 days, respectively). At least 25% of the larvae positioned in the intra in the individual experiment in the spring took only seven days to reach adulthood.

Canyon et al. (2013) found out that a reduction in longevity at low (34%) vs. high (84%) relative humidity in an Australian population of *Ae. aegypti* from a wet tropical climate. Mohammed and Chadee (2011) found out at relative humidity at 80%, the hatching rate was 98% at 24–25°C while at 34–35°C, the egg hatching rates declined to 1.6% after 48 hours. Costa et al. (2010) found that females *Ae. aegypti* mosquito responded to an increase in temperature by reducing egg production, oviposition time and changing oviposition patterns. Yang et al. (2009) found out that varying in temperature either low or high, posed significant impact to the development of mosquitoes. Delatte et al. (2009) reported that the minimal threshold of immatures stages development was found at 10.4°C and its optimum at 29.7°C. The shortest period for immature development were found at 30°C, with an average of 8.8 days. The optimum intrinsic rate of growth was observed between 25 and 30°C. The gonotrophic cycles were also evaluated, and the shortest cycles were found at 30°C (mean: 3.5 days). Monteiro et al. (2007) reported that the mean eclosion time increased with the temperature. Survival was strongly affected by higher temperature as well. Löwenberg Neto and Navarro-Silva (2004) found out that increased temperature positively affected the development speed where the combination of higher temperature regime and periodical and complete change of water increased the eggs viability and shortened the incubation time. Briegel and Timmermann (2001) reported as well that median larval development time from hatching to pupation was correlated inversely with temperature in which as the temperature increases, rate of development by day decreases.

Six studies examined both *Ae. aegypti* and *Ae. albopictus*, enabling direct species comparisons. Alto et al. (2015) reported that significant effects and interactions of species, humidity and larval competition on adult longevity in both *Ae. aegypti* and *Ae. albopictus*, with *Ae. aegypti* showing greater longevity than *Ae. albopictus* under most conditions. However, the direction and scale of the humidity effect on survival was not reported. Reiskind and Launibos (2009) has examined the effect of larval competition on adult survival in both species, and reported greater longevity in *Ae. aegypti* relative to *Ae. albopictus* and reached longevity on both species with reduced humidity (35% vs. 85% relative humidity).

Panigrahi et al. (2014) reported that in term of oviposition preference over medium with different concentration of sodium chloride (NaCl) in which distilled water as the control, *Ae. aegypti* laid less eggs compared to *Ae. albopictus* in the distilled water. There is no eggs were laid by female *Ae. albopictus* in the ovitrap containing 2.0% while for *Ae. aegypti*, minimum eggs were laid. However, in term of oviposition preference for different coloured ovistrips by *Aedes* mosquitoes, both species prefer the colour of black instead of white. In term of oviposition preference in water from different source, no eggs were laid by either species in the ovitraps containing seawater while negligible numbers of eggs were observed in ovitraps containing drain water. From the aspect of choice of oviposition medium (normal and larval holding water), both species laid a greater number of eggs in ovitraps containing larval holding water than oritraps containing distilled water. In response to size of ovitrap, both species did not lay eggs in the smallest used ovitrap but laid maximum number of eggs in the largest ovitrap. In term of oviposition cycle at different photoperiod regimens, both female *Aedes* species laid the maximum number of eggs in the fourth quarter of the light period, which gradually reduced thereafter on all the three days of the experiment. Outcomes from the study conducted by Chua et al. (2005) support the findings of Panigrahi et al. (2014) where it is reported that gravid female *Aedes* mosquitoes preferred containers with relatively easy access but not too open to external environmental influences for laying eggs. The dark surface of the containers served as the initial and long-range attractant to the breeding sites.

Bagny et al. (2013) reported that *Ae. aegypti* was drastically affected by temperature which is performing well only at around 25°C, at which it achieved its highest survivorship and greatest estimated rate of increases. Apart from that, *Ae. aegypti* was also more negatively affected by high population densities. In contrast, *Ae. albopictus* exhibited better population performance across a range of environmental conditions. Farjana et al. (2012) shared their finding in which mortality increased only at 35°C in both species. Mortality was higher on the high-level diet than on the low-level diet at

35°C, but not at other temperatures. Both species developed more quickly at higher temperatures with the range of 20–30°C; however, development was not enhanced at 35°C.

3 Material and methods

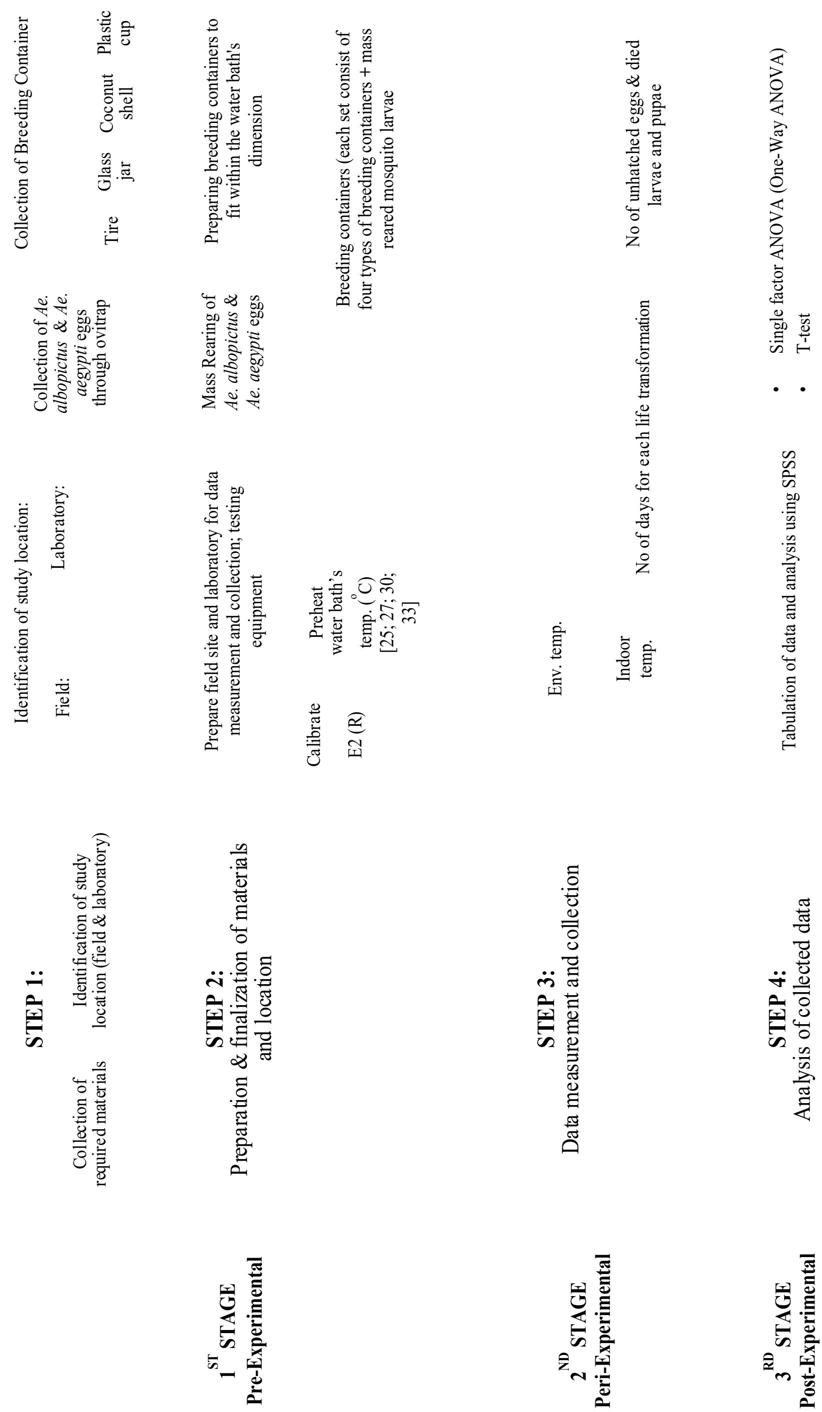
The strategy of this experimental study was premeditated in order to execute the research on both *Ae. albopictus* and *Ae. aegypti* under the laboratory-controlled environment. The research consisted of three main stages with four steps of procedures. The first stage (pre-experimental) was conducted prior to the core experimental study where the first step was executed at the field setting of natural environments. The aims of the first step are to collect wild strain of *Ae. albopictus* and *Ae. aegypti* eggs through the use of ovitrap devices that was placed at the suitable and preferable condition of the *Aedes albopictus* and *Aedes aegypti* mosquitoes around the campus. Another aims of the first step is prepare the selected breeding containers and identify the suitable site for field data collection procedures. The selected type of breeding containers (tyre, coconut shell, glass jar and plastic cup) was used in the second stage of this study. The second step of the first stage is to prepare the collected study materials for the next stage of the research and finalised the site for data collection, which represent both I/O setting. In this step, the collected *Ae. albopictus* and *Ae. aegypti* eggs was mass reared and the collected selected type of breeding containers was prepared to be fitted and usable for the next stage of the research.

The next stage of this research is the peri-experimental stage (second stage), which is consisted of third steps. This stage is the core and critical part due to the relevant and import data, which is correlated with the objectives of this study, is yielded from this stage. The third step is setting-up the laboratory water bath's temperature to the selected values of temperature that is at 25°C, 27°C, 30°C and 33°C, based on the results of reviewed previous studies. Once the temperature of water inside the water bath has reached the pre-set temperature to incubate samples, a total of 30 first instar larvae of *Ae. albopictus* that reared from the second step of first stage was allocated in the selected breeding containers. Then, the observation of development from the embryonic phase to adult phase was commenced and yielded data was rerecorded. The same step was repeated for a different species of mosquito that is *Ae. aegypti*. The final stage of this research strategy is the post-experimental stage, which is, comprises of the final step (fourth step). In this stage, the collected data yielded from the second stage was tabulated and analysed by using SPSS software in which one-way ANOVA, regression tool and t-test was used. Figure 1 shows the stage by stage of the research design.

4 Results and discussion

The characteristic of microclimate between the I/O study location are consisted of two main data which are the pattern of temperature and the pattern of wind velocity and relative humidity between these two sides of the study location.

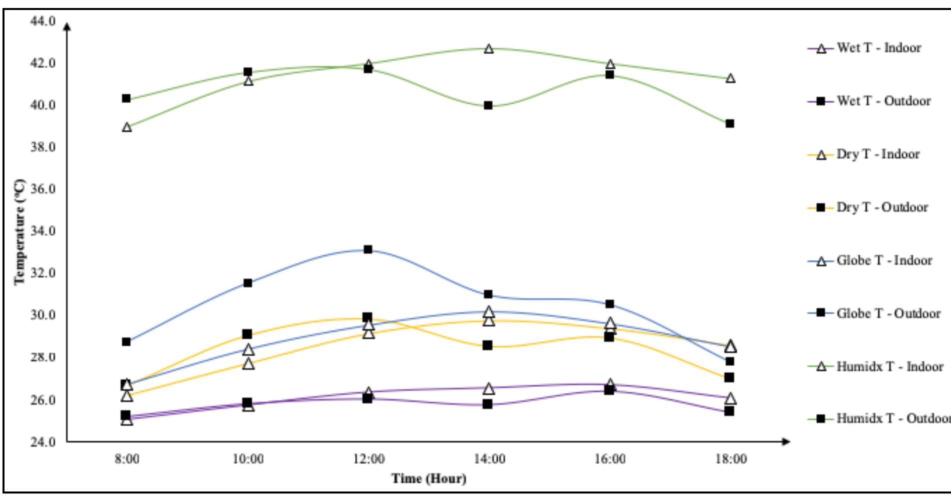
Figure 1 The outlines of the research stratagem that is consist of three stages and four steps involving field and experimental task



4.1 Temperature between I/O settings

As shown in Figure 2, the pattern of the measured type of temperature that is dry, wet, globe and humidx shows a difference reading between the I/O location. The wet temperature (represented by the purple line of colour) of indoor is slightly lower than the outdoor, which is 25.1°C and 25.2°C correspondingly at the hour of 08:00. However, at 10:00, the temperature of both I/O is identical and higher than the previous time, which is 25.8°C. At the time of 12:00 and consecutively at 14:00 and 16:00, the wet temperature of indoor is increasing, which is 26.4°C, 26.6°C and 26.7°C respectively, and at the time of 18:00, the temperature is starting to decrease to 26.1°C. In term of outdoor data, the pattern of the temperature has a fluctuation pattern of up and down. At the time of 12:00, the reading of temperature increases to be 26.0°C but then fall into 25.8°C at the time of 14:00. The reading is then increasing again into 26.4°C at the time of 16:00 and decreasing at the time of 18:00 to be 25.4°C. This pattern indicates that at the time of 08:00, there is a slight difference in both of the study location. However, the temperature of both study location is identical at the time of 10:00, but then the pattern starts to differ until the final sampling at the time of 18:00.

Figure 2 Distribution pattern of the profile of recorded temperature (°C) for an I/O location that is denoted with white triangle and black rectangular shapes as a representation for I/O location respectively (see online version for colours)



Note: T – temperature.

In comparison to the dry temperature, the data obtained and analysed for both study location of I/O is visibly different. The dry temperature for both I/O location is at 26.2°C and 26.7°C respectively at the time of 08:00. However, at the time of 10:00 and 12:00, the temperature reading of both study location of I/O is increasing from the initial reading which is 27.8°C and 29.2°C for indoor and 29.1°C and 29.9°C for outdoor, respectively. At the time of measuring hour of 14:00, 16:00 and 18:00, the dry temperature of indoor is higher compared to outdoor location.

Apropos with the globe temperature, the obtained reading for both location of I/O shows a clear distinction. At the time of 08:00, 10:00 and 12:00, the reading of globe temperature for indoor location is 26.8°C, 28.4°C and 29.6°C, respectively while for outdoor location, the collected reading is 28.8°C, 31.6°C and 33.1°C respectively with both locations experiencing steady increases between 1 to 2°C. The value obtained for globe temperature at the outdoor location is started to decline at the time of 14:00, 16:00 and 18:00 with temperature recorded is 31°C, 30.5°C and 27.8°C, respectively. However, for the indoor location, the recorded reading of globe temperature at the time of 14:00 is still showing an increase but then started to decline at the time of 16:00 and 18:00 with a value of 29.6°C and 28.5°C, respectively.

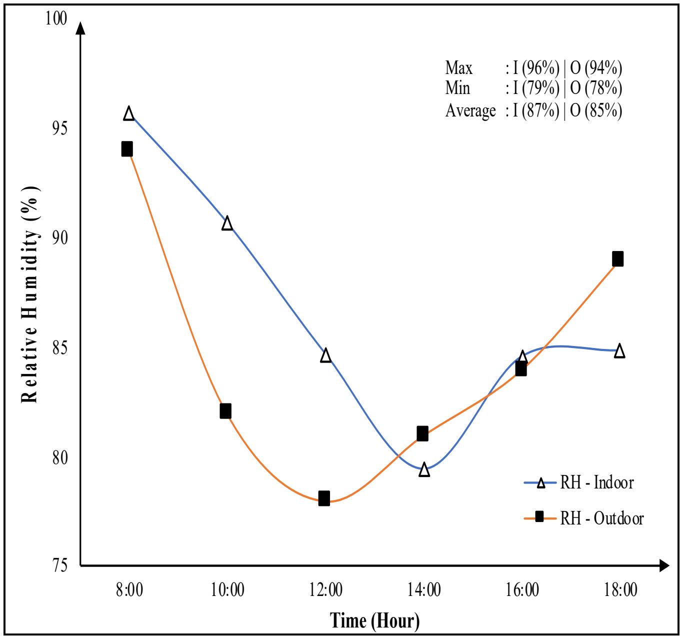
The obtained data of humidx temperature, indicated differences between I/O locations. The temperature for indoor location increases proportionally to the period of 08:00 until 14:00, starting with a temperature of 39°C until the temperature reaches 43°C. However, the temperature readings start to decrease by 1°C for each interval of two hours during which the final recorded temperature for the final time is 41°C. In term of outdoor recorded temperature, the value obtained at the first two intervals is slightly higher than the indoor temperature which is 40°C and 42°C at the time of recording which is 08:00 and 10:00 hours, respectively.

4.2 Pattern of relative humidity and wind velocity between I/O

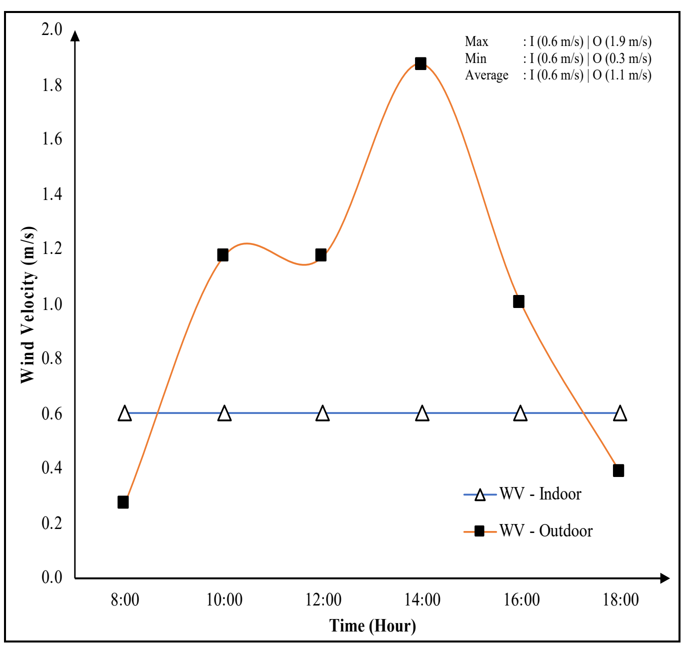
As shown in Figure 3(a), the distribution pattern of relative humidity for both I/O location indicated a substantial difference. However, the recorded data was slowly decreased against time for both locations. The recorded data demonstrate this at the sampling time of 08:00, 10:00, and 12:00 for both locations, which are respectively 96%, 91% and 85% of indoor location and 94%, 82%, and 78% for outdoor location. The obtained data for an outdoor location began to increase proportionally to the time in which the final recorded data at the last sampling hour is 89%. The recorded data for indoor location is still showing a decline until the time of 14:00 before the increase to be 85% and perpetually the same until the final sampling.

As shown in Figure 3(b), the line graph demonstrates the distribution of wind pattern for both I/O locations. The measured and recorded data for outdoor location indicated a movement of wind, which is occurred in the area starting from the sampling time of 08:00 until the final point of sampling hour. However, at first, the data shows increment from the initial time of sampling which is 0.3 m/s to be 1.2 m/s and perpetually for the next sampling hour before increase again to be 1.9 m/s and this is the highest recorded data in this part of observation before declining until the final sampling time which is 0.4 m/s at 18:00 hour. Conversely, the recorded data for the indoor location indicated that there is a slow and perpetually movement of wind against all sampling hours which is 0.6 m/s of wind velocity.

Figure 3 (a) Pattern of relative humidity for I/O location through time and (b) distribution pattern of wind velocity (m/s) for an I/O location that is denoted with white triangle and black rectangular shapes which represents I/O location respectively (see online version for colours)



(a)

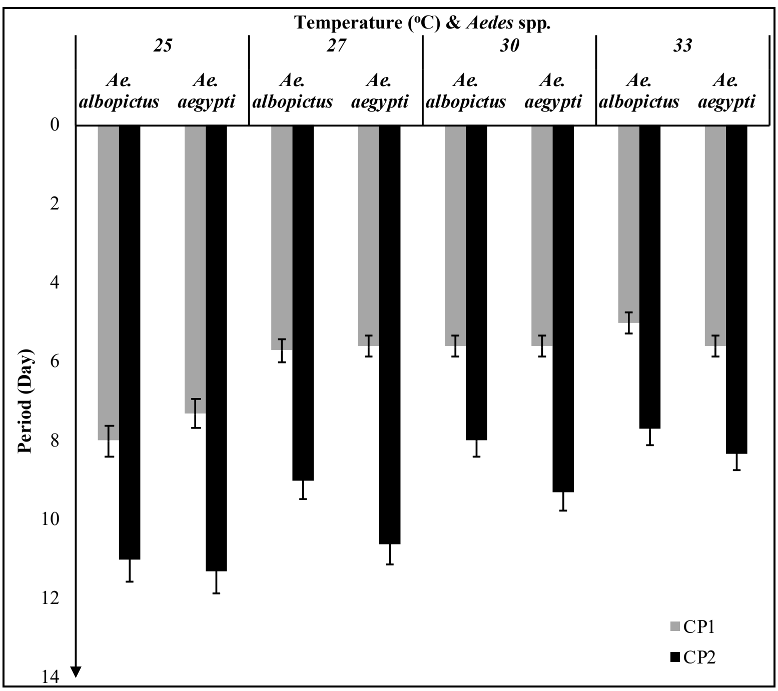


(b)

4.3 Immature development between *Aedes albopictus* and *Aedes aegypti* relative to temperature and breeding container

The difference of the number of days required for the commencement and cessation of pupation between these two species against the selected level of water temperature as shown in Figure 4 does not show the massive difference as the rate of development is equal or less equal or more equal of each other species. At the lowest selected temperature of 25°C, both *Aedes* species required more day for the commencement of pupation to take place. As the chosen temperature increasing to the highest selected temperature of 33°C, the number of day for the commencement of pupation of both *Aedes* species to take place were decreasing. The same trend occurs with the period of cessation of pupation for both *Aedes* species in which as the selected water temperature is increasing, the required number of the day for the cessation to take place is decreasing.

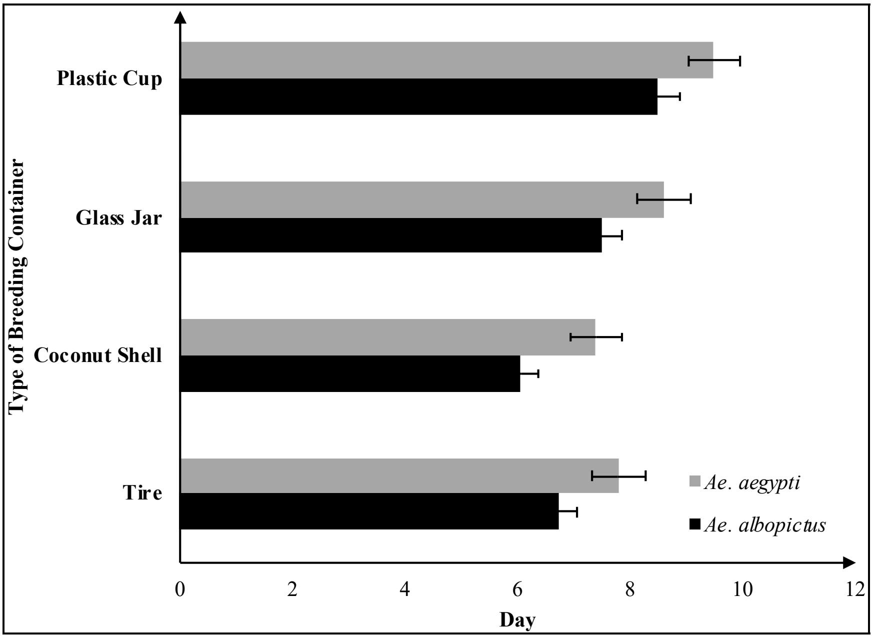
Figure 4 Effect of temperature to the commencement and cessation of pupation of *Ae. albopictus* and *Ae. aegypti*'s larvae



Note: CP1 – commencement period and CP2 – cessation period.

Among the four-selected type of breeding container that is tyre, coconut shell, plastic cup and glass jar as shown in Figure 5, the average period of *Ae. aegypti* were shortest in the coconut shell, followed by a glass jar, tyre and the last one was the plastic cup. The same situation occurred for the *Aedes albopictus* as well. In between of these two species, *Ae. albopictus* larvae experienced low developmental rate compared to *Ae. aegypti* against all four type of selected breeding containers. However, the gap of the day between these two species is not too palpable as the difference is only by a day or less.

Figure 5 Average day of *Ae. albopictus* and *Ae. aegypti* larval development based on different type of container in response to the different level of water temperatures



The lifecycle of a mosquito undergoes few stages before it reaches the ultimate level of adulthood. However, the success of the completion of each stage depends on the internal and external factor as well. In this study, two main factors were being assessed throughout the development cycle of two main vectors that is responsible for the endemic and fatal vector-borne disease. The two main factors are the temperature in the aquatic level and the type of breeding container that can have significant consequences for the regulation of new emerging adult mosquito population. These two main factors that were highlighted and the backbone of this current research are concurrent with the adapted conceptual framework that is formulated by Morin et al. (2013) where it exhibits the interconnected of relationships between variables, habitat availability for mosquito larvae which includes temperature and immature habitat in the environment level.

As stated by Murrell et al. (2011), the alarming rise of dengue epidemiology has been highlighted to haunt 40% of the world population; where disease severity varies from asymptomatic infection to undifferentiated DF or possible develop into life-threatening manifestations such as DHF and DSS. Apart of the rapid development although crucial and essential for the nation global economy that has contributed to the transmission of endemic dengue viruses, according to Freedman et al. (2006), the increasing concerns are also driven by increased travel of tourists and military personnel. Through this study, crucial information related to the survivorship and fecundity of the mosquito can be obtained, as it is critical to the transmission of the diseases that is concurrent with the statement by Nur Aida et al. (2011).

The study by Okogun (2005) provide the similar statement with Nur Aida et al. (2011) as well where the developmental period of the aquatic stages of *Aedes albopictus* lifecycle which could provide information in recognising the pattern of distribution of dengue cases based on the different and changing climate in Malaysia. The pattern of aquatic stage development period of *Aedes* species mosquitoes in different temperatures provides necessary information in understanding the outcome of seasonal changes throughout the year in Malaysia. The yielded data can be integrated with other sources and secondary data from multiple agencies to produce a set of a surveillance system for early detection of dengue incidence.

Environmental conditions influence mosquito vector life history and demography in several ways. As mosquitoes are ectotherms, their development and survival are dependent on the temperature of the surrounding environments (Blanford et al., 2013). Based on the recorded and analysed result of this current study for temperature variation, there is a significant difference between I/O location. For each variable (wet temperature, dry temperature, globe temperature and humidx temperature) that was measured, the different recorded data exhibit a pattern of varying fluctuation of temperature between I/O.

The maximum temperature recorded for each of the variables in indoor location is 26.7°C, 29.8°C, 30.2°C and 43°C, respectively while for an outdoor area, the maximum temperature recorded is 26.4°C, 29.9°C, 33.1°C and 42°C, respectively. In term of minimum recorded temperature to each of the studied variables, for indoor location is 25.1°C, 26.2°C, 26.8°C and 39°C, respectively while for the outdoor location, the recorded minimum temperature is 25.2°C, 26.7°C, 27.8°C and 39°C. The averages of recorded temperature for both I/O location are 26.1/25.8°C, 28.5/28.4°C, 28.9/30.5°C, and 41/41°C, respectively. In term of relative humidity between I/O location, the maximum, minimum and average data is 96%/94%, 78%/79% and 87%/85%, respectively. For the maximum, minimum and average data of wind velocity against I/O location shows a different pattern where for indoor data, the value is a constant of 0.6 m/s respectively while for outdoor, the data is 1.9 m/s, 0.3 m/s and 1.0 m/s, respectively. Thus, seasonal variation in temperature can have numerous impacts on mosquito demography and transmission potential. This was also supported by the study of habitat characterisation of *Aedes* spp. breeding in urban hotspot area, which is conducted by Dom et al. (2013). In the conclusion of the referred study, environmental characteristics such as dissolved oxygen, turbidity, conductivity; wind velocity, ambient temperature and relative humidity may affect the selection of breeding habitat by *Aedes* species for their survival and population densities.

Ae. albopictus and *Ae. aegypti* mosquitoes lay their eggs and subsequently develops their eggs into larvae in domestic water storing containers, rain-breeding objects including a wide variety of discarded materials as well as natural water retaining structures like tree holes and plant axils that are often abundant in peri-domestic environments. According to Ferdousi et al. (2015), there is a wide range of potential larval development sites for these mosquito species that vary in size and location in the environment. Though many different types of containers can serve as development sites for vector mosquitoes, in some cases selected breeding containers can produce large numbers of larvae/pupae or some containers are sufficiently abundant to be efficient sources of larvae/pupae.

Four types of breeding containers were selected and studied for its suitability for the breeding site of *Aedes* mosquitos. The four type of breeding container is tyre, coconut shell, glass jar and plastic cup where these types of breeding containers are concurrent with the outcome of the study conducted by Paul et al. (2018) for the main types of positive containers and most productive containers by season. Based on the recorded data of temperature for each of the selected breeding container, the range of conserved heat from the initial time of recording to the final time of recording is between 25.4°C to 29.0°C for indoor location while for the outdoor area, the range of temperature is 24.7°C to 29.1°C. The type of breeding container that has conserved the highest heat is glass jar while the lowest conserved heat of type of breeding container is coconut shell for both I/O location. Thus, these 'key containers' are either highly productive or highly efficient, and both drive the local abundance of vector mosquitoes.

The significance of both *Ae. albopictus* and *Ae. aegypti* as an essential vector of arbovirus diseases such as dengue, chikungunya, zika and yellow fever has led many researchers to search for useful and novel techniques to minimise the risk of virus transmission (Kittayapong et al., 2008). In this current study, the effect of temperature to the embryonic developmental rate was assessed by looking on the aspects of commencement of pupation and cessation of pupation against the selected temperature of 25°C, 27°C, 30°C and 33°C. The outcome of this research indicates that as the increase in temperature from 25°C to 33°C, the commencement and the cessation of pupation is decreasing in time (day). The shortest period for commencement of pupation is identified at the temperature of 33°C with the average of 5.0 while for the cessation of pupation was detected at the temperature of 33°C as well with the average of 7.7. The outcome is concomitant with the result of the study conducted by Briegel and Timmermann (2001), Delatte et al. (2009) and Li et al. (2014). The study conducted by Briegel and Timmermann (2001) identified that median larval developmental time from hatching to pupation was correlated inversely with temperature, lasting seven days at 32°C and up to 28 days at 12°C. Duration of the pupal period also varied from 2–3 days at 32°C to 7–12 days at 12°C.

Delatte et al. (2009) found out that the shortest periods of immature development were at 30°C within an average of 8.8 days. In that study, eight constant temperatures that are 5°C, 10°C, 15°C, 20°C, 25°C, 30°C, 35°C and 40°C was selected to study the biological parameters of immature development, survival, longevity, fecundity and gonotrophic. Apart of the shortest period of immature growth, the minimal threshold of immatures development was identified as well at 10.4°C and its optimum at 27.9°C. The finding of Li et al. (2014) concluded that the development time of *Ae. albopictus* is shorter at the higher temperature. Apart from that, at the range of 25–30°C, it is the optimum temperature for the mosquitoes to develop and if too high or low in temperatures will suppress the development of the mosquitoes. This is proven when Li et al. (2014) identified that all stages (egg, larva, pupa) of the mosquitoes could not develop at 10°C. Their study observing the changes at different development stages and gonotrophic cycle at different temperature conditions of 10°C, 15°C, 20°C, 25°C, 30°C, 35°C and 40°C in which the full developmental cycles were compared during different temperatures.

Ae. albopictus has the ability to breed in natural and artificial habitats as well, such as tyres, barrels, rainwater gulley, catch basins and drinking troughs (Diallo et al., 2010). Natural habitats consist of phytotelmas (water bodies held by terrestrial plants, e.g., tree holes) and rock pools (Delatte et al., 2008). For this current study, four type of breeding key container was selected which is tyre, glass jar, plastic cup and coconut shell. The selected container can be assigned or categorised into two main group of containers as stated by Diallo et al. (2010) which is natural habitat (coconut shell) and artificial habitat (glass jar, plastic cup and tyre). Based on the outcomes of this study, the rate of development of *Ae. albopictus* immature stage in an organic (natural) classified container exhibit a shorter rate of development compared to the inorganic (artificial) container. This situation can be due to the characteristic (such as turbidity, pH, TOC, magnesium, calcium and sodium) of the breeding container itself (Madzlan et al., 2016).

Mosquitoes are more likely to breeds in breeding containers as the site for embryonic developmental stages in the urban surroundings. According to Getachew et al. (2015), almost all mosquitoes species would select to oviposit in a less lighting area or shaded where in that particular site, the temperatures are lower paralleled to the place that directly exposed with sunlight. Getachew et al. (2015) further explains the findings that the types of containers, water quality, and conditions of water containers are necessary for breeding. Findings by Reiskind and Zarrabi (2012) and Day (2016) stated that the preference of oviposition of female mosquito is a container with a small surface diameter in size, deep level of water to minimising the risk of habitat drying and containing organic matter properties. Day (2016) also explain that *Aedes* species preferred natural and artificial containers such as abandoned tyres, cans, bottles and other as the oviposition sites.

The aberrations of the surface water temperature of a container depending on the heat capacity of the surface containers (Bergman et al., 2011). For example, under the same set of heating a different size of the water container, small volume of water container will be heated faster compared to a large proportion of water container due to the difference of capacity of the water inside of the containers to absorb and retain the observed heat. Thus, a container with a smaller in size only needs a small amount of heat to warm the water compared to the large in size of containers. Furthermore, coherent with the study conducted by Medronho et al. (2009), the emergence of pupae from larvae acquired approximately eight to nine days in a plastic container. Apart from that, this study also includes other types of containers such as coconut shell and glass bottles due to this type of breeding container were the most abundantly found firmly with the environment of the human.

In this current study, the embryonic development in term of commencement of pupation and cessation of pupation for both species indicated that as the selected temperature increase, the required day is decreasing. This outcome is concurrent with the finding of the study conducted by Thahsin (2011) indicated that both species of *Ae. albopictus* and *Ae. aegypti* developed more quickly at higher temperatures within the range of 20°C to 30°C but the temperature of 35°C, there is no enhancement of the development. Thahsin's (2011) study is focusing on the effects of temperature, diet and the presence of congeneric species on the embryonic stage of both species.

Both species were reared at four constant temperatures of 20°C, 25°C, 30°C and 35°C with low or high diets. Between the four selected temperatures, the rate of mortality increases at 35°C in both species. In term of the selected type of breeding container, both species perform (shortest day) in the organic (natural) container that is coconut shell while the longest day has occurred in the inorganic (artificial) container, which is the plastic cup. This outcome is concomitant with the statement of finding by Daugherty et al. (2000), Juliano (2009) and Murrell et al. (2011) where the population growth of *Ae. albopictus* and *Ae. aegypti* larvae is closely associated with the nature of the resource available. A study conducted by Darriet (2016) found that there is the occurrence of development between these two species in the container filled with plant material.

Both *Ae. albopictus* and *Ae. aegypti* share similar larval habits, including development in the breeding container either it is artificial or natural. As a result of their overlapping geographic distributions and shared microhabitats, invasions by these species have impacted the distribution and abundance of one another, as well as of other resident mosquito species (Lounibos, 2002). However, the outcome of competition between these species is highly context-dependent and affected by the nature of aquatic resource (Juliano, 2009). According to Murrell and Juliano (2008), the alteration of outcome could be caused by detritus type, shifting a situation of intense competition to a state of low interspecific competition and stable coexistence between these two main *Aedes* species.

5 Conclusions

The primary objective of this study is to determine the association between temperature and types of breeding containers against the developmental rate of immature stages of *Ae. albopictus* and *Ae. aegypti*. The finding of this study indicates that there is a positive association between the developmental rate in the aquatic phase for both *Aedes* species to the selected water temperature and the type of breeding containers. As the temperature increases, the rate of development shortened in the number of days. At the highest selected temperature of 33°C, both *Aedes* species were able to complete the aquatic lifecycle into adult phase indicating that both *Aedes* species are able to survive at the highest selected temperature for the purpose of this study. Among the selected water-holding container, shortest development was recorded in the coconut shells, followed by tyres, glass jars and plastic cups for both *Aedes* species. These findings provided valuable baseline information on the potential effects of climate change on the bionomics of *Ae. albopictus* and *Ae. aegypti* in future projection of *Aedes* density towards an improve vector control.

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