LIFE CYCLE OF OIL PALM BAGWORM, *Metisa plana* WALKER (LEPIDOPTERA: PSYCHIDAE) AT DIFFERENT TEMPERATURES UNDER CONTROLLED ENVIRONMENT

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ABSTRACT

Temperature is one of the most important abiotic factors that affects insect life cycle. Unpredictable local climate changes in Malaysia had caused the outbreak of bagworm, *Metisa plana* for over five decades. This had led to a major problem of oil palm yield production. Hence, it is significant to study the nature of this pest especially their life cycle to prevent further outbreak. This study is expected to provide *M. plana* surveillance program planning that can prevent massive damage of defoliation from occurring. The application to control bagworms should be applied at the right time especially during the crucial climate changes that could trigger the bagworm's life cycle. The main objective in this study is to evaluate the life cycle of oil palm bagworm, *M. plana* in different degrees of temperature. This study was conducted under controlled conditions in the laboratory from October 2017 until October 2018 with different ranges of temperature between 16°C to 40°C. The duration in days from egg to adult was observed and recorded daily. This study found that bagworms were able to adapt and complete life cycles at a selected temperature between 20°C to 36°C, but did not survive at 16°C and 40°C. The duration observed of the completed life cycle of this species significantly decreased with the increase in temperature. The duration in days of the completed life cycle of temperature at 20ºC, 24ºC, 27.5ºC, 32ºC and 36ºC was approximately about 122.2±0.87, 108.4±1.74, 99.6±1.89, 81.2±1.70 and 64.8±1.25 respectively. The optimum temperature of bagworm's survival rate was at 32°C with a total percentage at 63.48%. This study provides basic fundamental information on the life cycle of bagworm, *M. plana* especially for oil palm growers. Hence, growers will have better pest management plans to control this bagworm species related to different temperatures and prevent yield loss of fresh fruit bunch (FBB) of oil palm plantation per acre.

Keywords: Temperature, outbreak, oil palm, life cycle, bagworm, *Metisa plana*, controlled environment

ABSTRAK

Suhu merupakan salah satu faktor abiotik yang penting kepada serangga terutama dalam kitaran hidupnya. Perubahan iklim yang tidak kosisten di Malaysia semakin sukar untuk diramalkan telah menyebabkan berlakunya serangan ulat bungkus. Sejak dari lima dekad lagi, spesies ulat bungkus, *Metisa plana* ini telah dikenali sebagai serangga perosak kepada pokok kelapa sawit di Malaysia. Keadaan ini akan memberi impak terutama kepada pengeluran hasil kelapa sawit. Oleh itu, ianya amat penting untuk mengkaji kitaran hidup spesies ulat bungkus ini bagi meningkatkan kefahaman sifat unik spesies ini dengan mendalam. Kelimpahan spesies ulat bungkus ini harus dikawal pada waktu yang tepat terutama apabila berlakunya perubahan iklim yang mendadak. Oleh itu, objektif utama bagi kajian ini adalah untuk mengkaji kitaran hidup *M. plana* pada beberapa suhu tetap yang berbeza. Kajian ni dijalankan di dalam kondisi makmal yang terkawal dari Oktober 2017 hingga Oktober 2018 dengan julat suhu yang berbeza di antara 16°C hingga 40°C. Pemerhatian kajian ini dicatatkan pada setiap hari bermulanya dari peringkat telur sehingga ke peringkat dewasa. Ulat bungkus ini mampu melengkapkan satu kitaran hidup pada suhu terpilih di antara 20°C hingga 36°C, tetapi tidak dapat bertahan pada suhu 16 ° C dan 40 ° C. Berdasarkan hasil pemerhatian, tempoh kitaran hidup spesies ini menurun dengan ketara selari dengan suhu yang semakin meningkat. Tempoh kitaran hidup lengkap ialah pada suhu 20ºC, 24ºC, 27.5ºC, 32ºC dan 36ºC masing-masing pada 122.2 ± 0.87, 108.4 ± 1.74, 99.6 ± 1.89, 81.2 ± 1.70 dan 64.8 ± 1.25 hari. Manakala suhu optimum bagi kadar kelangsungan hidup ulat bungkus adalah pada suhu 32 ° C dengan jumlah peratusan sebanyak 63.48%. Kajian ini memberikan maklumat asas mengenai kitaran hidup *M. plana* yang mampu mengurangkan kadar serangan ke atas kelapa sawit. Kajian ini memberikan makluman awal berkaitan kitar hidup, M. plana khususnya kepada para pengusaha ladang. Maklumat ini dapat digunapakai dalam merancang pengurusan pengawalan ulat bungkus ini bergantung kepada suhu sekitaran bagi mengelakkan pengurangan hasl tandan buah (FBB) di ladang sawit per ekar.

Kata kunci: Suhu, wabak, kelapa sawit, kitaran hidup, ulat bungkus, *Metisa plana*, persekitaran terkawal

INTRODUCTION

Nowadays, the climate in Malaysia has become more inconsistent and unpredictable (Tang 2019). Thus, the unusual climate change is one of the factors that trigger the bagworm, *Metisa plana* outbreak (Ibrahim et al. 2013; Noor Hisham et al. 2013). Besides, bagworm is one of the major pests to oil palm plantation especially toward FELDA estates in Malaysia (Noor Hisham et al. 2013). According to Noor Hisham et al. (2013), *M. plana* are the most abundant species of leaf-eating caterpillars that exist in almost all FELDA estates. The outbreak problem of this species found had occurred especially around the area at Southern Perak, Peninsular Malaysia. Moreover, due to the rising temperature it will affect the rate of development, growth, survival, activity and its dispersal (Ibrahim et al. 2013).

The defoliation damage by *M. plana* about 10-13% caused the yield to decrease around 30-40% over two years during the outbreak (Kalidas 2012). Hence, the damages of the defoliation caused the rate of photosynthesis of the palm oil to decrease. This leads to massive defoliation toward oil palm plantation mainly in Malaysia (Kok et al. 2011; Noor Hisham et al. 2013; Sudarsono et al. 2011). The defoliation of oil palm trees is about 50%, which can cause severe yield loss up to 10 tons of fresh fruit bunch (FBB) per acre (Kalidas 2012). The defoliation by bagworm will unlikely to be noticeable, until it causes serious attack especially during the outbreak (Kamarudin & Arshad 2016). The estates such as FELDA Besout, FELDA Trolak in Perak and FELDA Sahabat, Sabah had encountered the problem for many years in controlling the early infestation which caused severe outbreaks (Noor Hisham et al. 2013).

The outbreak of this bagworm species still occurs continuously until today (Kamarudin & Arshad 2016). Thus, if the outbreak of *M. plana* continuously occurs it does affect the economy sector of plantation (Halim et al. 2017). It is important to understand the natural biology of this bagworm species especially on the life cycle (Kok et al. 2011). Therefore, the life cycle needs to be studied under different temperatures (Ibrahim et al. 2013). In a previous study, the optimum temperature of *M. plana* was at 30°C and the bagworm was able to survive at temperature 35°C (Ibrahim et al. 2013). This study provides recent data of *M. plana* life cycle under different degrees of low and high temperature. Therefore, this study could become one of the references to growers in preventing the bagworm outbreak.

MATERIALS AND METHODS

Rearing Process

Rearing of *M. plana* was established by collecting the newly mated pupae at FELDA Gunong Besout, Sungkai, Perak where the outbreaks were occurring. The bagworms were reared under a degree of temperature at 16ºC, 20ºC, 24ºC, 27.5ºC, 32ºC, 36ºC and 40ºC from October 2017 until October 2018. These temperatures were selected based on the previous study done by Ibrahim et al. 2013, with modifications. All temperature monitored for every eight hours and the humidity of the room was maintained between 75% until 95% RH (Relative Humidity), (Ibrahim et al. 2013). Each of the treatments contains five replications. Each of the replication represents one mated pupae. The emergence of the neonate that hatched from the eggs was about 130 to 200 individuals. However, not all the neonates are able to develop into the first instar stages for a few hours after the emergence. There were ten collapsible rearing cages were needed for each of the temperatures. Each of the collapsible rearing cages contained 15 plastic containers. The rearing was done by placing the mated pupae in the clear plastic cup capped with small holes and placed in the collapsible rearing cage. Then, five neonates (larvae) were put on each of the oil palm leaflets that were placed in an upright position after a few hours emerged from the egg (Kok et al. 2011). The leaflet was changed for every three days and the water in the plastic cups was changed daily to maintain the freshness of the oil palm leaflets.

The eggs of the *M. plana* were partly enclosed in a sheath inside the female pupae (Kok et al. 2011). In this study, the larvae were studied undergo six instars' stages. The identification of *M. plana* under larvae stages was indicated based on (Kok et al. 2011). The measurement was taken on the first day of neonate's emergence until the larvae develop into pupae stages. Adult of *M. plana* is morphologically different in both male and female. The adult male of this bagworm emerged as a moth (Kok et al. 2011). The wing moth takes flight on its emergence day and lives for about two to three days only (Rhainds et al. 2009). Meanwhile, the adult female emerged wingless which looks like a maggot that is legless (Kok et al.2011). Adult female will release sex pheromone to attract the male to identify which female has not been mated (Rhainds et al.2009). Then, this adult female will leave the case directly after laying the eggs in the case and died a few hours later (Kok et al. 2011).

Temperature and Humidity Monitoring

The warm temperature at 32°C, 36°C and 40°C were set up using a portable home space electric fan heater. Meanwhile, the cold temperature at 16°C, 20°C and 24°C were set up using an air conditioner. Temperature 27.5°C was selected as room temperature of the laboratory. These temperatures were chosen during the preliminary study based on the study done by Ibrahim et al. 2013. Each of the selected temperatures were observed, monitored, tested and stabilized for about a week during the preliminary study. The air cooler was set up and adjusted in order to maintain the Relative Humidity of the room above 75% RH. The water tank of the air cooler was refilled for every 12 hours.

Data collection

The egg hatching's day for each temperature was observed daily and recorded. The number of neonate emergence was studied and recorded. In this research, the larvae stages were observed under sixth instars. The identification was indicated based on Kok et al. (2011) measurement. Both length of the case and caterpillar was measured daily. The life cycle of *M. plana* in each of the different degrees of temperature was recorded and studied.

RESULTS AND DISCUSSION

Early Development of the Larvae

Figure 1 shows the percentage survival of egg emergence of the neonate in this study. The data recorded was the mean of total five replications for each treatment temperature. The neonate that hatched from the egg was about 130 to 200 individuals. The temperature at 16ºC and 40ºC; the eggs of *M. plana* were unable to emerge or survive. The mortality was due to the extreme temperature. The eggs were unable to tolerate or respond under this kind of environment condition. However, *M. plana* can survive and complete its life cycle under temperatures of 20ºC, 24ºC, 27.5ºC, 32ºC and 36ºC. Besides that, the percentage differences in the egg emergence of the neonate that survives also might be possibly caused by the sibling neonates' cannibalism or could be due to unfertile eggs (Rhainds & Ho 2002).

However, the huge different shows in the result were caused by different temperatures. The temperature at 32ºC shows the highest percentage of egg emergence of the neonate at 87%. The lowest percentage of surviving egg emergence of neonate was 35% at the temperature of 20ºC. These differences show that the newborn larva has no life experience which is known as a "clean state" where everyone starts its new life (Sheikh et al. 2017). Therefore, most of the bagworm in this egg emergence stage was unable to adapt to that certain temperature.

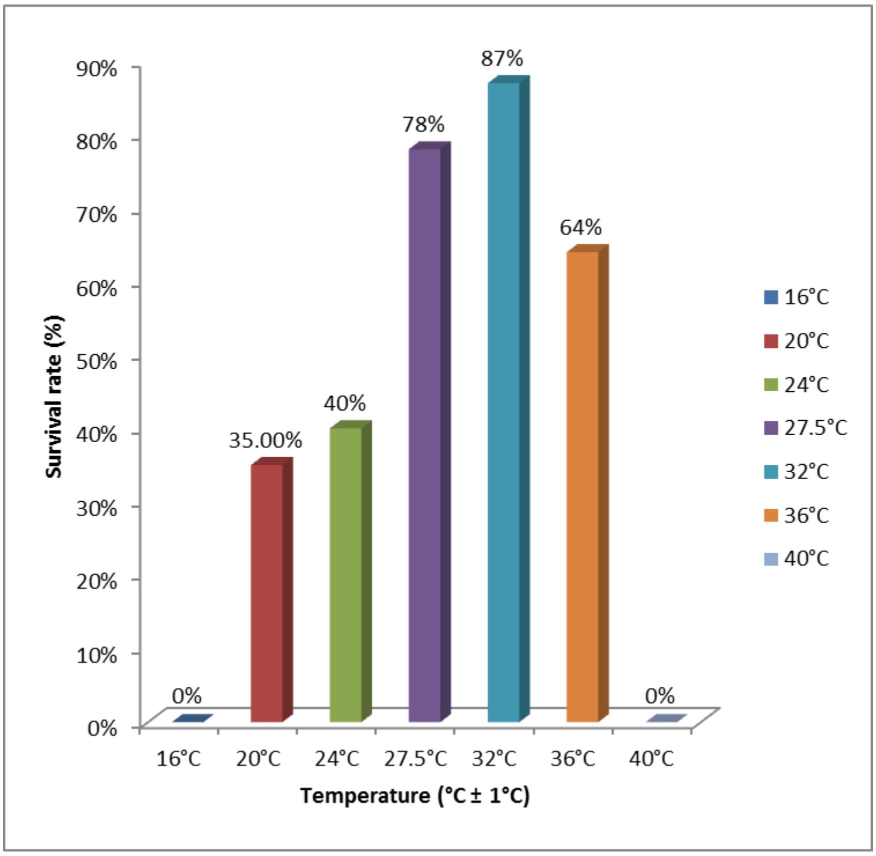

Figure 1. Percentage of *Metisa plana* neonate emergence at different temperature

Figure 2 shows the percentage of neonates that are able to survive and develop into its first instar stage. The first instar stage was observed and recorded after a few hours' emergence of the neonate from the eggs. The neonate that was able to construct its first portable bag around its body was successful to develop into the next stages. The neonate starts to feed as soon its crawl out from the eggs (Rhainds et al. 2009). The portable bag of cases gives protection to its internal body from the external condition (Sugiura 2016). In this stage, the temperature at 32ºC shows the highest percentage which consists of those able to develop into first about 99.33% instar stages. Meanwhile, the lowest percentage was about 93% consisting of that able to develop into first about 99.33% instar stages at temperature 20°C.

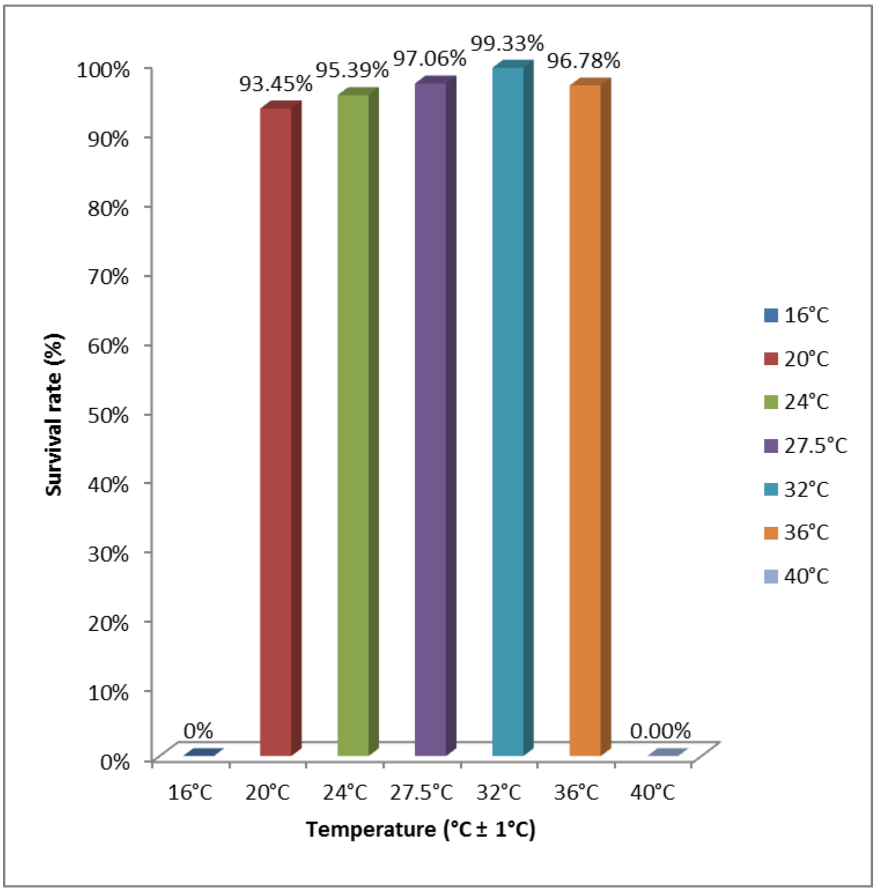

Figure 2. Survival rate of *Metisa plana* from neonate to first instar stage at different temperature

Life Cycle of *Metisa plana*

Egg stage

Figure 3 shows the duration in days of egg emergences at different temperatures in this study. The result shows that the higher the temperature, the shorter the duration of egg to hatch. The longest duration for the egg to emerge was at 20ºC that took 17±0.79 days. Meanwhile, the shortest duration for the egg to emerge was at 36ºC that took 6.8±0.31 days. At this stage, the successful neonate starts to feed and make their silk portable bag (Kok et al. 2011) from the foliage of the oil palm leaflets. Hence, the silk is tough enough as it is made from a lot of leave's pieces (Cheong et al. 2010; Lynch et al. 2014).

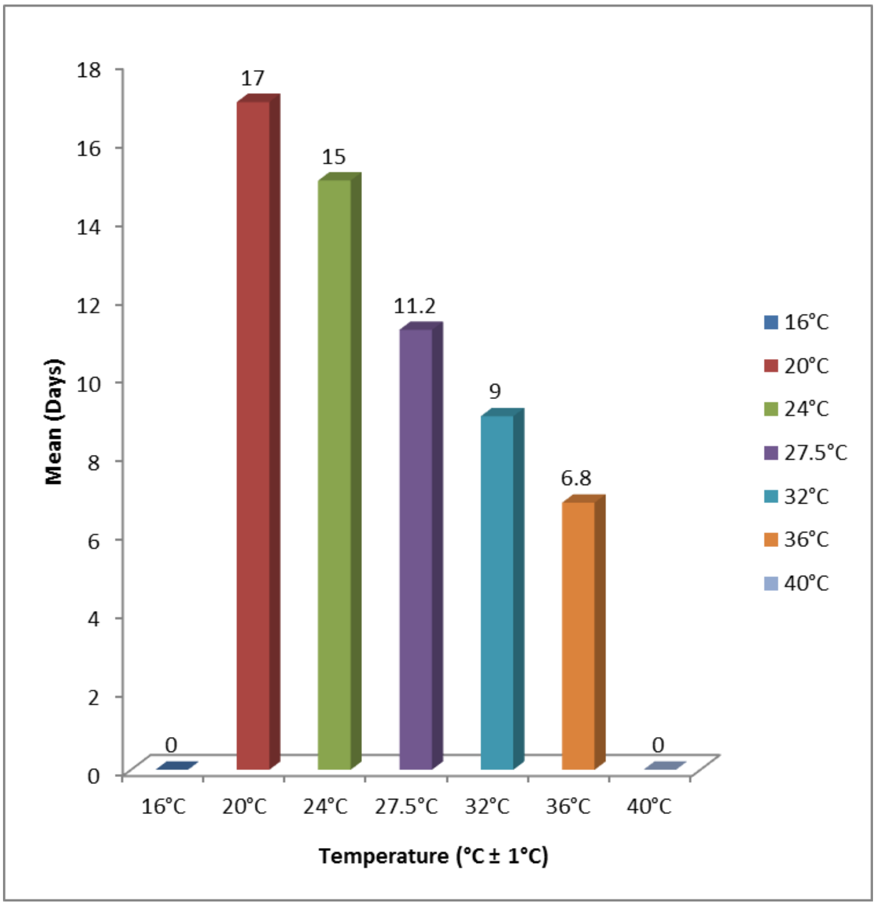

Figure 3. Duration (days) of *Metisa plana* egg emergences at different temperature

Larvae stage

The results in this study were significant and align with Ibrahim et al. (2013). The duration of the life cycle was increasing when the temperature is decreasing between 20ºC until 36ºC. The larvae *M. plana* undergo six instar stages in this study. The larvae show differences in feeding activity and mobility under different temperature. These behaviors were affecting the duration of growth development that constructs the life cycle of bagworm, *M. plana* at each of the temperature.

20ºC: Figure 4 shows the duration of *Metisa plana* larvae stages under temperature of 20ºC. The average duration of *M. plana* life cycle under temperatures of 20ºC was 122.2±0.87 days. The smallest movement and feeding activity by larvae were observed in this temperature. Besides, the portable case was very fragile between the first instar until the fifth instar. At this temperature, the first instar took 80.8±2.09 days to molt into the sixth instar stage. The sixth instar took 13.4±2.02 days to molt into the next stage. The pupation duration was 11±1.15 days before emerging into adult. Hence, the rightest time to control the bagworm before the larvae entering the late instar stage was at the first 67.2 days at this temperature.

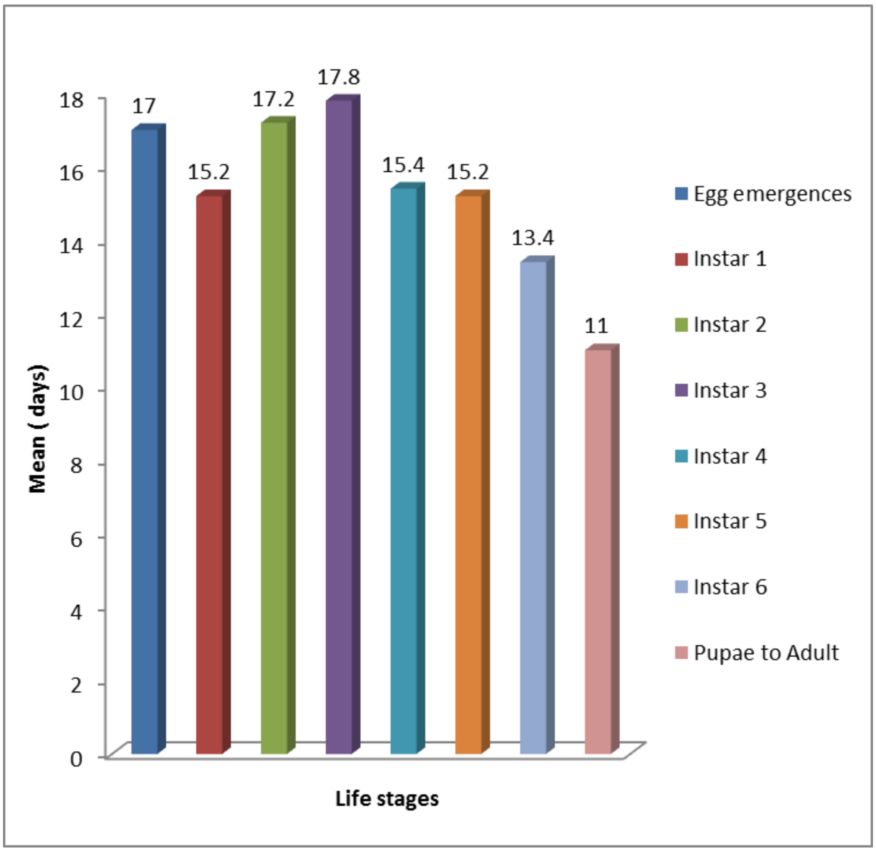

Figure 4. Life cycle of *M. plana* under temperature of 20ºC±1ºC

24ºC: Figure 5 shows the duration of *Metisa plana* larvae stages under temperature of 24ºC. The average duration of *M. plana* life cycle under temperatures of 24ºC was 108.4±1.74 days. The behavior shown by the bagworm such as mobility and feeding activity were better than at 20ºC. The portable case is tougher compared to temperatures of 24ºC. In this temperature, the total development from the first instar into sixth instar stages took 72.8±1.66 days. Then, the sixth instar took 12±0.73 days to molt into the next stages. The pupae of *M. plana* took 8.6±0.51 days to emerge as an adult. Hence, under this temperature the rightest time suggested controlling this bagworm was at the first 62 days as, at 63th days the larvae entered late instar stage.

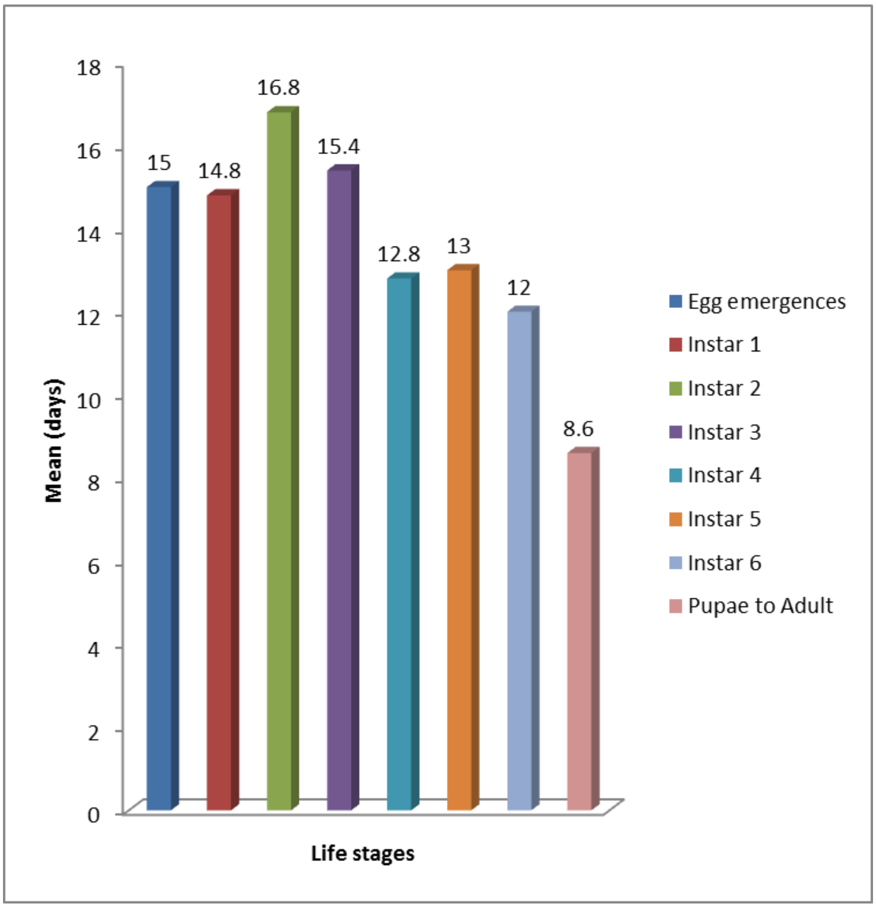

Figure 5. Life cycle of *M. plana* under temperature of 24ºC ±1ºC

27.5ºC: Figure 6 shows the duration of *Metisa plana* larvae stages under temperature of 27.5ºC. This temperature was the room temperature of the laboratory. The average life cycle from egg to adult under this room temperature was 99.6±1.89 days. The first instar approximately took 68.4±1.85 days to molt into sixth instar stages. The larvae under this temperature were more active in feeding and mobility. Then, the sixth instar took 11.8±1.85 days to molt into pupae. The pupation period took 8.2±2.36 days to emerge as an adult. Therefore, under this temperature the most effective time to control the bagworm was at the first 55.8 days as, within these durations the case of the early instar stage were still fragile.

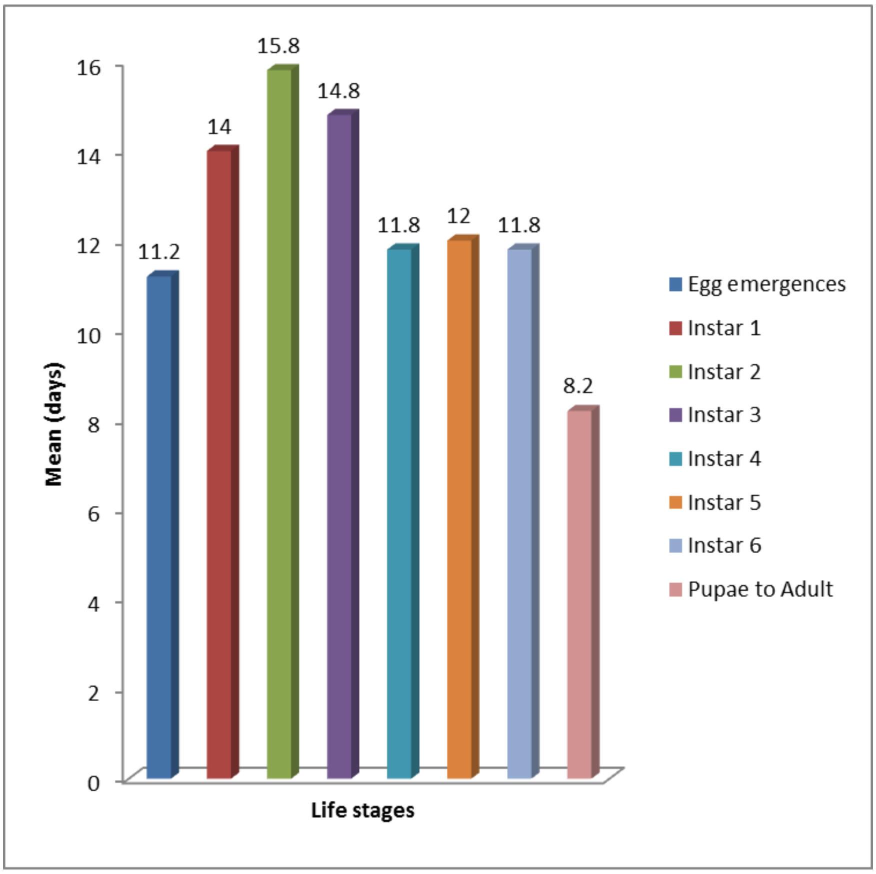

Figure 6. Life cycle of *M. plana* under temperature of 27.5ºC±1ºC

32ºC: Figure 7 shows the duration of *Metisa plana* larvae stages under temperature of 32ºC. The average duration of *M. plana* life cycle under temperatures of 32ºC was about 81.2±1.74 days. At this temperature, the mobility and feeding behavior of larvae were the most active. The rising level of the activity of the bagworm might be due to the mechanism of adaptation toward high temperature (Sheikh et al. 2017). Besides, at this temperature the larvae feeding activity was the highest. This could be due to the dryness condition. Bagworm does need more water to retain in its body. Therefore, by increasing its feeding activity and thickness of the case could prevent water loss from the body.

The total duration of larvae stages from the first instar to the sixth instar only took about 56.4±1.26 days. Then, the sixth instar molt into pupae stages took 9±1.78 days. The final stage of pupae emerges as an adult and takes approximately 6.8±1.70 days. Therefore, under this temperature the rightest time suggested to control this bagworm was at the first 41.8 days before the bagworm entered late instar stage. At a late instar stage, the cases of the bagworm were tougher and pesticide unable to penetrate the cases. Besides, at 32ºC was the optimum temperature for *M. plana*.

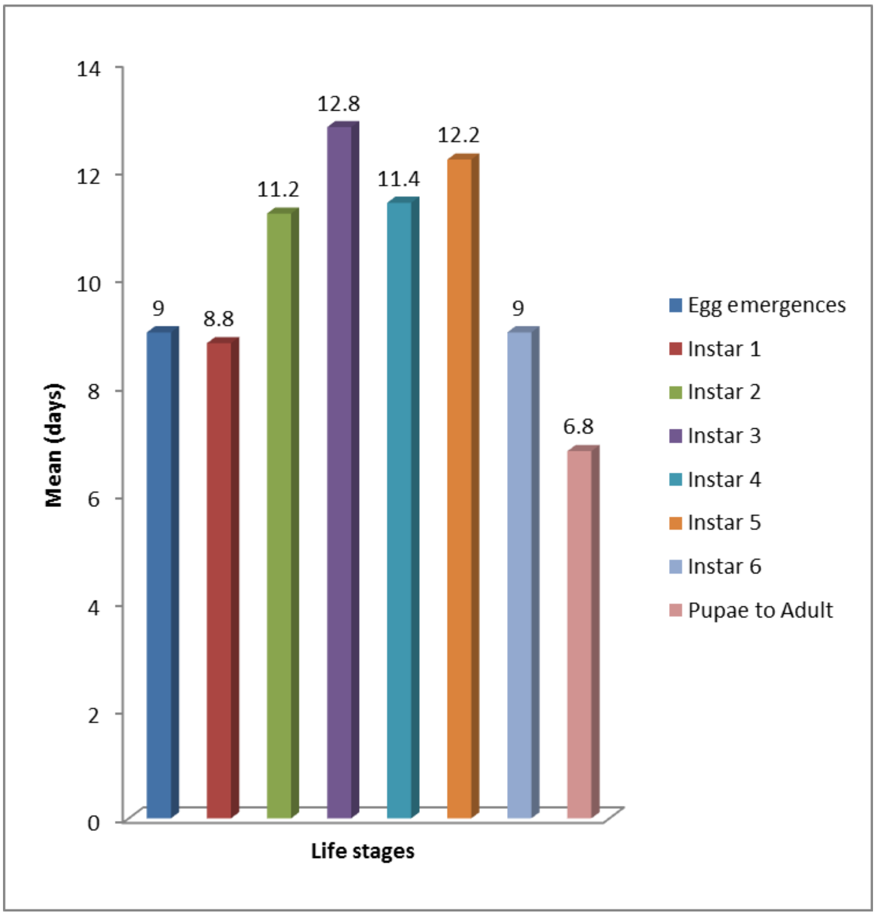

Figure 7. Life cycle of *M. plana* under temperature at 32ºC±1ºC

36ºC: Figure 8 shows the duration of *Metisa plana* larvae stages under temperature of 36ºC. The life cycle of this bagworm species is the shortest under this temperature. As recorded, the average duration of the life cycle was approximately 64.8±1.25 days. The activity level of mobility and feeding were the highest under this temperature. Thus, at this temperature would trigger the duration of the bagworm life cycle to become shorter. The total of larvae stages from the first instar to the sixth instar took 45.4±2.19 days. The life cycle of insects usually shortens especially at the larval stages when the temperature is increasing (Jaworski & Hilszczanski 2013). Then, the sixth instar took 7.2±1.17 days before entering the pupae stage. The pupae emerged as an adult and took 5.4±1.25 days. Hence, under this temperature the most effective time recommended to control *M. plana* was at the first 33.6 days as within these days the bagworm were able to control as it still at its early instar stage.

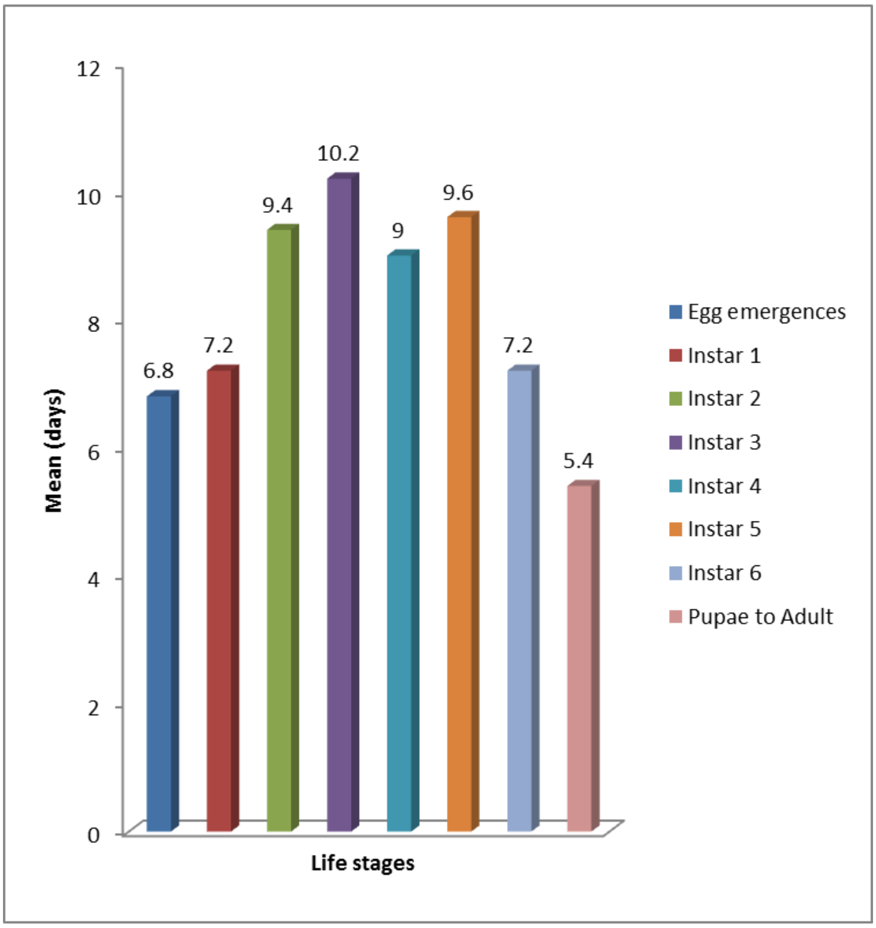

Figure 8. Life cycle of *M. plana* under temperature of 36ºC±1ºC

Adult Stage

Adult of *M. plana* is different in both male and female. The adult male of this bagworm emerges as the moth (Kok et al. 2011). This adult male takes flight on its emergence's day and lives for about two to three days only (Rhainds et al. 2009). Meanwhile, the adult female emerged wingless which looked like a maggot that is legless (Kok et al. 2011). The adult female will release sex pheromone to attract the male in order to identify which female has not been mated (Rhainds et al. 2009). The adult female will leave the case directly after it laid the eggs in the case and it will die a few hours later (Kok et al. 2011).

Figure 9 shows the survival rate of *M. plana* from egg to adult stages at different temperatures. The bar chart shows the increasing percentage of survival rate of bagworm from the temperature of 20ºC to 32ºC. However, at 36ºC the percentage of survival rate was fluctuating into 38.05%. The optimum temperature of *Metisa plana* in this study was at 32ºC as its survival rate was recorded highest at 63.48%. Thus, under this temperature the probability outbreak of this bagworm species is highest.

Most of the estate during the outbreak tends to use chemical control to keep the level of the population below the action threshold (Yap 2000). However, the use of chemical control brings disadvantages such as hard to degrade, causing pollution and bringing harm to human health in the long term (Felsot & Racke 2006). It is also recommended to reduce the usage of this pesticide in order to keep the number of bagworm's natural enemies increasing. The natural enemies such as predators and parasitoids are able to decrease and reduce the outbreak of *M.*

plana. Therefore, it is better to have an instant control during early infestations by establishing the Pest Monitoring System (PMS) which is divided into three stages such as; i) Alert and Detection, ii) Census and Assessment and iii) Action and Follow-up (Noor Hisham et al. 2013).

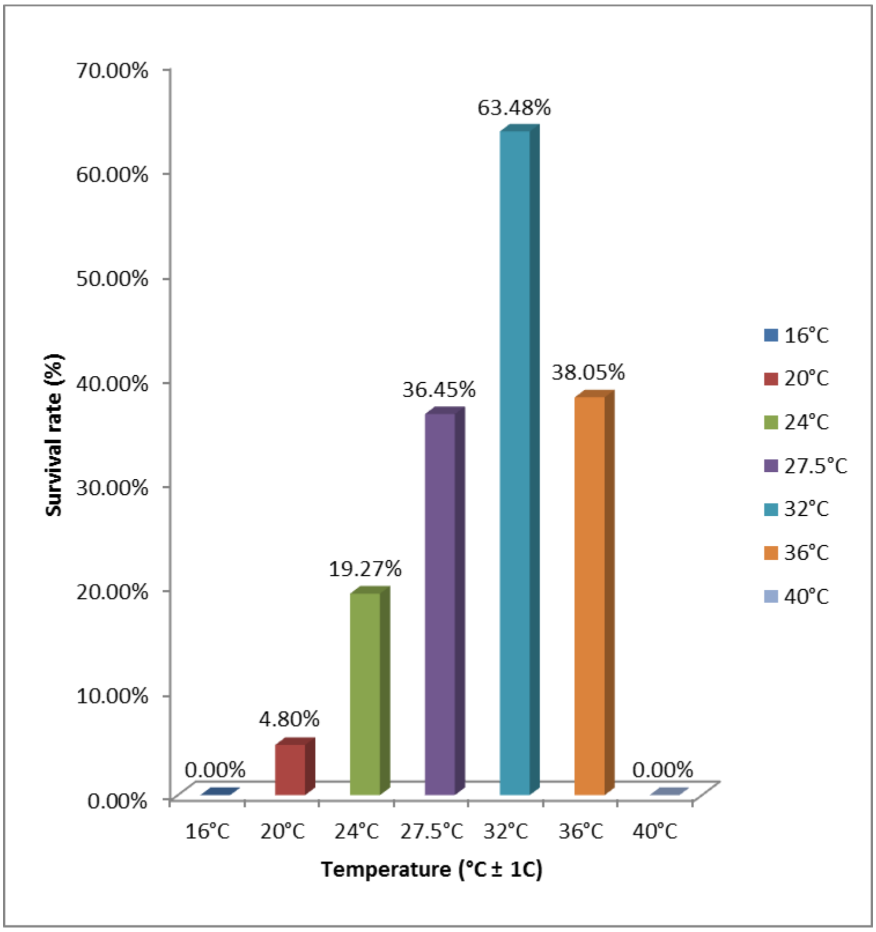

Figure 9. Survival rate (%) of *M. plana* from egg to adult at different temperature

CONCLUSIONS

This study will provide understanding in the life cycle of this bagworm species, *M. plana* especially during unpredictable and inconsistency climates. The management could reduce the attack of the bagworm based on the data in this research by controlling the larvae at its early instar stages. Therefore, management is able to make crucial decisions to control the bagworm's population especially to prevent the outbreak.

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