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# STUDY ON THE ABIOTIC FACTORS INFLUENCING THE POPULATION DYNAMICS OF THE BAGWORM, *Metisa plana* WALKER (LEPIDOPTERA: PSYCHIDAE), IN AN OIL PALM PLANTATION IN PERAK, MALAYSIA

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## ABSTRACT

Bagworm infestation can significantly impact oil palm production leading to crop losses up to 40%.This is especially critical among smallholders where management measures are usually delayed. Gaining insight into the influence of environmental variables on bagworms can aid in developing a more effective pest control approach. This study examined the impact of abiotic conditions: temperature, humidity, and rainfall on bagworm population in selected oil palm plantations in Perak, Malaysia. A study on interaction between bagworm *Metisa plana* populations with abiotic conditions was carried out at a smallholder oil palm plantation in Perak at regular intervals of 1-2 weeks per month during a span of 3 years (2018-2019 and 2021) using anemometer. Whilist the rainfall data was obtained from the Meteorological station. Change in temperature had a weak positive correlation (r=0.0024) on bagworm population during the early stages (larvae 1 to larvae 3), a moderate positive correlation (r=0.184) during the late stages (larvae 4 to pupae), and a slight positive correlation (r=0.061) with population of bagworm. Rainfall shows a positive correlation with *Metisa plana* populations, whereas relative humidity exhibits a negative correlation across all stages and populations of bagworms. The data indicated that variations in temperature and rainfall potentially influence bagworm populations. However, a comprehensive understanding of this impact necessitates with advanced Integrated Pest Management (IPM) approaches, pest monitoring and the utilisation of modelling tools as mitigation strategies.

**Keywords:** Abiotic condition, integrated pest management, *Metisa plana*, population dynamics

## ABSTRAK

Serangan ulat bungkus memberi kesan signifikan terhadap pengeluaran kelapa sawit, dengan potensi kehilangan hasil sehingga 40%. Keadaan ini lebih kritikal dalam kalangan pekebun kecil persendirian, di mana langkah pengurusan diambil lebih lewat. Memahami pengaruh faktor persekitaran terhadap populasi ulat bungkus adalah penting dalam merangka strategi kawalan perosak yang lebih berkesan. Kajian ini menilai kesan keadaan abiotik seperti suhu, kelembapan relatif, dan hujan terhadap populasi ulat bungkus di ladang kelapa sawit terpilih di Perak, Malaysia. Interaksi antara populasi Metisa plana dan faktor abiotik telah dikaji di sebuah ladang kelapa sawit milik pekebun kecil di Perak pada selang masa tetap iaitu setiap 1-2 minggu sebulan selama tempoh tiga tahun (2018-2019 dan 2021) menggunakan anemometer, manakala data hujan diperoleh daripada stesen meteorologi. Analisis korelasi menunjukkan bahawa perubahan suhu mempunyai korelasi positif yang lemah (r=0.0024) terhadap populasi ulat bungkus pada peringkat awal (larva 1 hingga larva 3), korelasi positif sederhana (r=0.184) pada peringkat akhir (larva 4 hingga pupa), dan korelasi positif lemah (r=0.061) terhadap keseluruhan populasi. Hujan menunjukkan korelasi positif dengan populasi Metisa plana, manakala kelembapan relatif menunjukkan korelasi negatif bagi semua peringkat pertumbuhan ulat bungkus. Hasil kajian ini menunjukkan bahawa variasi suhu dan hujan berpotensi mempengaruhi populasi ulat bungkus. Walau bagaimanapun, pemahaman yang lebih komprehensif mengenai kesan ini memerlukan pendekatan Pengurusan Perosak Bersepadu (IPM) yang lebih sistematik, pemantauan perosak yang berterusan, serta penggunaan alat pemodelan sebagai strategi mitigasi yang berkesan.

**Kata kunci**: Keadaan abiotik, pengurusan perosak bersepadu, Metisa plana, dinamik populasi

## INTRODUCTION

Persistent and escalating bagworm infestations threaten the productivity of oil palm plantations in Malaysia. As severe bagworm outbreaks continue ravaging plantations across Perak, Johor, and Kuala Selangor, they are now expanding into Pahang and Negeri Sembilan (Salim et al. 2012). The situation has reached a critical point. The infestation at FELDA Besout, which persisted since 2002, now covers a staggering 1,394 hectares. Outbreaks of *Metisa plana* could cause up to 40% yield loss and it takes about two years to fully recover (Rahmat et al. 2021). Despite decades of control efforts, the problem is continuing to degrade. Predators and parasitoids have been widely recognized to be useful in controlling pest populations, particularly bagworms (Halim et al. 2018). The issue of bagworm outbreaks falls back on the reluctance of some owners of the affected holdings and smallholdings to conduct control operations. The infection has not been contained despite larger plantations paying enormous sums of money. The population of bagworms without control often increased above its threshold limits, affecting neighbouring plantations (Ramlah et al. 2007).

Population dynamics involves quantifying changes in population size across successive generations and examining the factors contributing to these changes. This includes analyzing birth rates, death rates, immigration, and emigration, as well as the interactions among these elements. Understanding population dynamics is essential for addressing issues related to resource allocation, urban planning, and sustainable development (Begon et al. 2021; Keyes & Galea 2016). Factors influencing population dynamics are varied and could be density-dependent, environment and resource-dependent, imperfectly density-dependent and territorial. Since temperature is the most important environmental factor affecting insect population dynamics, it is expected that global climate warming could trigger an expansion of their geographic range, increased overwintering survival, increased number of generations, increased risk of invasive insect species and insect-transmitted plant diseases, as well as changes in their interaction with host plants and natural enemies (Sandra et al. 2021). For bagworms, temperature, rainfall and humidity have been identified to contribute on bagworm dynamics. The weather significantly influences the prevalence and occurrence of insect pests, as it affects their survival, development, and reproduction. Recent studies have demonstrated that rising temperatures and altered precipitation patterns, driven by climate change, directly impact pest outbreaks and distribution (Pureswaran et al. 2018; Stange 2010; Soroye et al. 2020). These findings highlight the critical role of climatic factors in shaping insect pest populations and underscore the need for climate-resilient pest management strategies.

Temperature is a crucial and extensively researched climatic factor in the field of insect bioclimatology, which focuses on the relationship between insects and weather conditions. The rate of growth, development, activity and dispersal of insects is affected by temperature (Enting & Latip 2021; Ibrahim et al. 2013). In laboratory investigations, reproductive and demographic statistics of insects generally improved with increasing temperature until the optimum was reached (Ibrahim et al. 2013). Enting and Latip (2021) identified an optimum temperature for the life cycle of *M. plana* under a 32°C treatment in a prior investigation while Wood and Norman (2019) stated that the life cycle of *M. plana* lengthens when the temperature drops below 15°C. For *Thyridopteryx ephemeraeformis*, the inside temperature of bags of *M. plana* is greater than ambient air; however, this is influenced by several factors, including the species of host plants and the size of the bags (Smith & Barrows 1991). The elevated temperatures led to reduced development time and increased productivity and abundance.

More rainfall translates to increased moisture in habitats, which has been reported to influence insect populations in tropical plantations, including oil palm (Norman et al. 2016). While increased moisture can enhance the survival and proliferation of certain pests, excessive rainfall can also contribute to insect mortality. For example, research has shown that high rainfall can dislodge early instar larvae of *Metisa plana* from oil palm fronds, reducing their survival rates. Similarly, outbreaks of *Sexava nubila* in oil palm plantations have been linked to rainfall patterns, as wet conditions can enhance egg survival and larval development. However, excessive precipitation may also promote fungal infections that act as natural regulators of pest populations. Studies on *Pteroma pendula* have indicated that prolonged rainfall can increase the prevalence of entomopathogenic fungi, leading to significant larval mortality. Similar patterns have been observed in other agricultural pests; for instance, in sugarcane plantations, heavy rainfall was found to reduce *Scirpophaga excerptalis* populations by washing away eggs and larvae. Likewise, in cassava plantations, torrential rain disrupted populations of *Phenacoccus manihoti* by removing their protective wax layers, leading to high mortality (Moran et al. 1987). These findings underscore the dual role of rainfall in both supporting and suppressing insect populations, ultimately shaping the dynamics of pest outbreaks in oil palm ecosystems.

The key to addressing this crisis lies in understanding how abiotic factors influence the population dynamics of bagworms. Unfortunately, there is currently limited scientific data available on the impact of ecological factors on bagworm population. The study in Perak focuses on understanding bagworm outbreaks due to its unique climate, severe infestations, spreading outbreaks, lack of region-specific data, and the need to develop better pest control methods tailored to Perak's conditions. For instance, Al-Obaidi et al. (2021) mentioned that, a 2021 study evaluated bagworm infestations and beneficial parasitoids in an oil palm plantation at FELDA Gunung Besout 2, Perak, highlighting the ongoing challenges faced by the plantation due to these pests. Therefore, this study aimed to investigate and elucidate the intricate relationship between abiotic factors such as temperature, humidity, and rainfall and the population dynamics of bagworms (*M. plana*) in oil palm plantations in Perak, aiming to provide insights for developing more effective and targeted pest management strategies.

## MATERIALS AND METHODS

**Samples of Bagworm, *Metisa plana* Walker (Lepidoptera: Psychidae)**
Samples of larvae and pupae of *M. plana* were collected from the infected fields. The samples were divided into two stages which are early stages (larvae 1 to larvae 3) and late stages (larvae 4 to pupae).

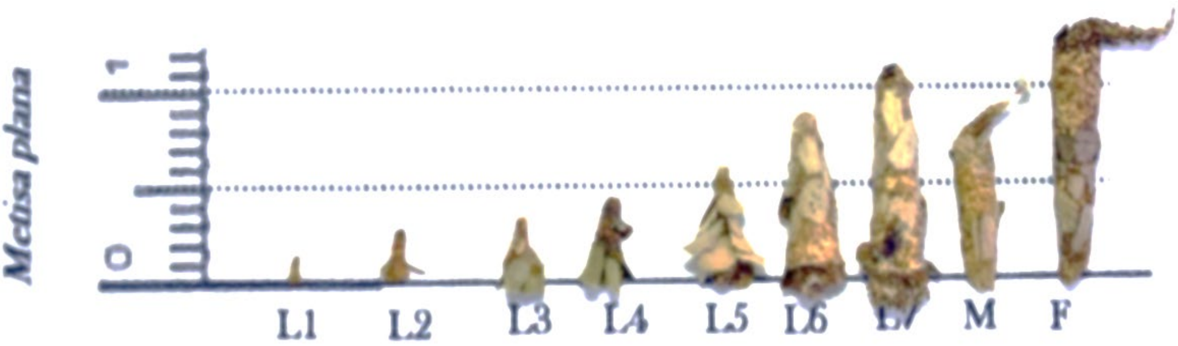



Figure 1. Larval stages of bagworm: early stages (L1 to L3) and late stages (L4 to pupae)

**Study Sites**
The research area was located in Perak smallholdings, Malaysia (4.8073° N, 100.8000° E), where the affected sites were covered with oil palm trees aged between 10 to 15 years. The study spanned three years (2018, 2019, and 2021); however, data collection was not conducted in 2020 due to restrictions associated with the spread of Coronavirus Disease (COVID-19). A total of approximately 60 sampling sites were selected within the smallholdings of Perak, focusing on areas experiencing significant bagworm infestations.

**Data Collection**
An initial census of bagworms was conducted to enumerate and document an initial population of bagworms. One percent of the outbreak region was examined by selectively cutting one fronds of palm from every ten palms in every path of rows. The fronds were inspected for evidence of recent damage to ascertain the number of larvae and pupae on both sides of frond number 17. The frond number 17 was chosen because it had a rich nutrient content and a favourite bagworm feeding area (Standard Operating Procedures 2016). The temperature ranged between 27-39°C over the day, while the humidity ranged from 75% to 95%.

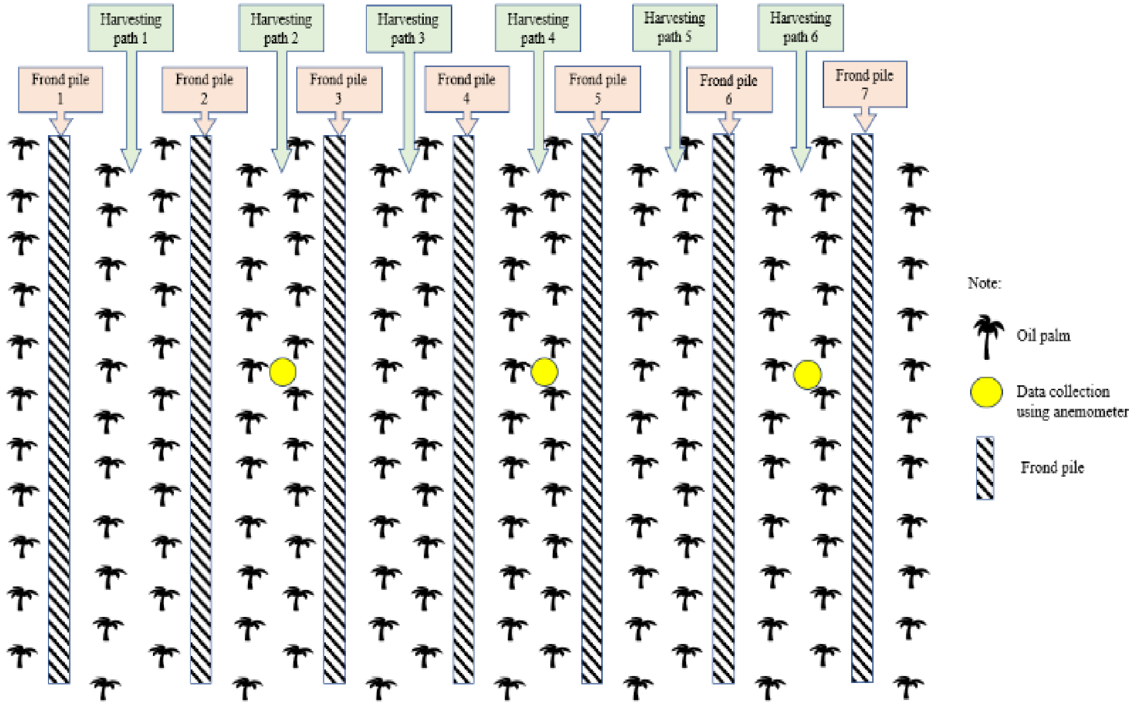



Figure 2. Location of data collection using anemometer in oil palm plantation

**Abiotic Data (Temperature, Humidity And Rainfall) Collection**

The data on temperature and humidity were gathered using an anemometer at regular intervals of 1-2 weeks per month during a span of three years (2018-2019 and 2021). The temperature ranged between 27-39°C over the day, while the humidity ranged from 75% to 95%. These values are consistent with Malaysia's equatorial climate, where annual maximum temperatures typically reach around 32.01°C and minimums hover around 25.45°C (Zawiah et al. 2019). Relative humidity in oil palm plantations generally exceeds 85%, creating a favorable environment for oil palm cultivation (Norman et al. 2021). These climatic conditions align with the established patterns observed in Malaysia, which is characterized by warm and humid weather throughout the year (MetMalaysia n.d.).

**Data Analysis**

A regression analysis was conducted using SigmaPlot version 14 to examine the relationship between environmental parameters (temperature, humidity, and rainfall) and the population dynamics of bagworms. The regression model aimed to determine the extent to which variations in these climatic factors influence fluctuations in bagworm populations over time. Additionally, a Pearson correlation analysis was performed at a significance level of 0.05 to assess the strength and direction of the relationships between individual environmental variables and bagworm population trends. The Pearson correlation coefficient (r) was used to quantify the degree of association, with positive values indicating a direct relationship and negative values suggesting an inverse relationship. The statistical analyses were conducted to identify significant predictors of bagworm outbreaks and to provide insights into the environmental factors driving population changes in oil palm plantations.

## RESULTS AND DISCUSSION

The mean result of temperature for this study was 29.9°C where the maximum and minimum temperature recorded was 39.2°C and 25.2°C (Table 1). On the other hand, it was found that the mean rainfall observed was 229.4 mm with the maximum rainfall recorded at 576 mm in Table 1. The mean for humidity in this study observed was 74.9% where the maximum and minimum of humidity recorded was 89.9% and 51.4% in Table 1.

Table 1. Data summary of abiotic factors for Perak during 2018-2019 & 2021

| | **Temperature (°C)** | **Humidity (%)** | **Rainfall (mm)** |
|---|---|---|---|
| Minimum | 25.2 | 51.4 | 0 |
| Maximum | 39.2 | 89.9 | 576 |
| Average | 29.9 | 74.9 | 229.4 |

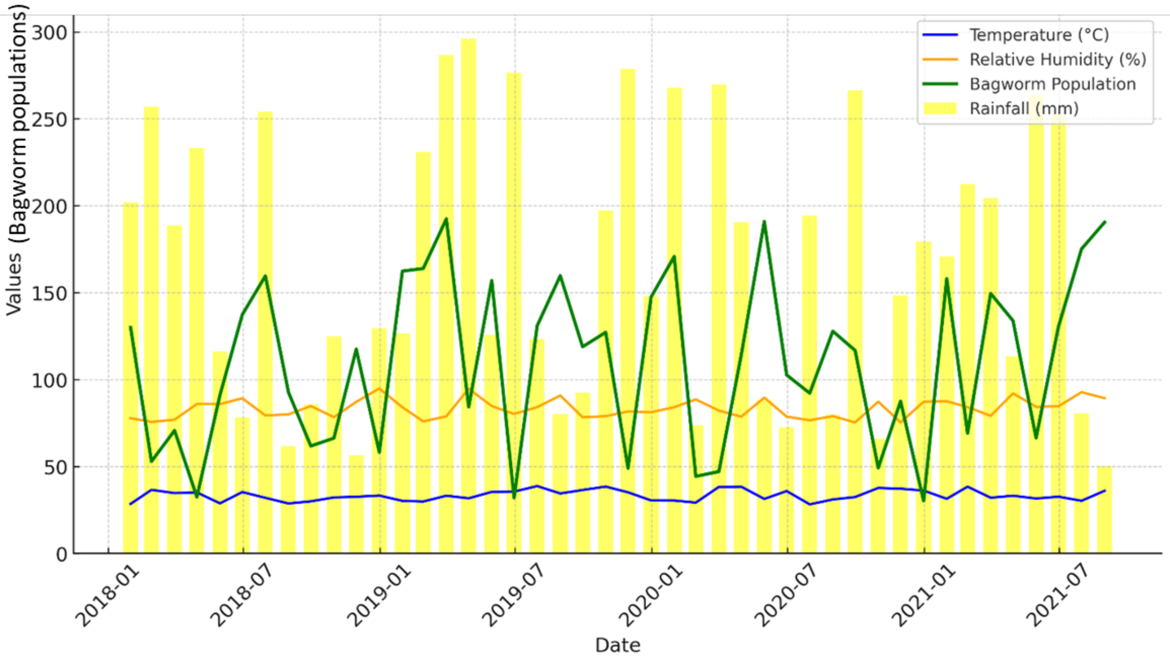



Figure 3. Abiotic factors versus population dynamic of bagworm from 2018-2021

Bagworm populations appear to be influenced by a combination of temperature, relative humidity, and rainfall. Warmer temperatures (Figure 3, blue line) tend to coincide with increased population growth, as higher temperatures accelerate larval development and reduce the time to maturity (Muturi et al. 2023). However, extreme heat may limit population growth if it surpasses the species' thermal tolerance. Relative humidity (Figure 3, orange line) shows an inverse relationship with bagworm populations. Higher humidity fosters the proliferation of natural enemies like entomopathogenic fungi, which infect and kill bagworms, as supported by Basri et al. (1995). Additionally, high humidity may increase egg mortality due to fungal infections and drowning, further suppressing populations. Rainfall (Figure 3, green line) exhibits a more complex relationship. Moderate rainfall supports host plant growth, improving food availability for bagworms, which could explain the positive correlation with population increases (Cheong et al. 2010). However, excessive rainfall may disrupt the bagworm life cycle by washing away larvae or reducing feeding opportunities. In previous studies, relative humidity has been observed to have a negative correlation with *Metisa plana* populations. For instance, research conducted in oil palm smallholdings in Johor, Malaysia, found that while temperature and rainfall had minimal effects on bagworm populations, relative humidity exhibited a negative correlation (r = -0.203) with *M. plana*. This suggests that higher relative humidity levels may suppress bagworm populations, potentially due to factors such as increased activity of natural enemies or unfavourable conditions for bagworm development.

According to Ibrahim et al. (2013), all stages of *M. plana* did not endure at 15°C and 40°C. Ibrahim et al. (2013) also state that the duration of all life stages was considerably shorter at 35°C. The results of this study indicate a positive correlation between temperature and *M. plana*, with P is 0.124 (r = 0.0.250) for the early stage and P is 0.166 (r = 0.184) for the late stage (Figure 3). The population of both bagworm stages was higher at higher temperature between 28°C and 31°C. Enting and Latip (2021) in their study found that the higher temperature shows rapid abundance of *M. plana*. The temperature at 32ºC shows the highest percentage of developing into first instar stages about 99.33% (Enting & Latip 2021). The total duration of larvae stages from the first instar to the sixth instar took about 56.4±1.26 days when temperature at 32°C. 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. The bagworm was more tolerance at a late instar stage, making pesticide more difficult against them.

Temperature is one of the most important and widely studied climatic factors in insect bioclimatology (Ullah et al. 2024). Moreover, temperature affects the rate of growth, development and dispersal of insects (Howe 1957). According to Enting and Latip (2021), the egg hatches faster at higher temperatures. Enting and Latip (2021) discovered that bagworms could adapt and complete their life cycles at temperatures ranging from 20°C to 36°C, but did not survive at 16°C or 40°C. The mobility and feeding behavior of larvae were the most active at 32°C (Enting & Latip 2021). 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 temperature was frequently found to influence the growth of larvae and pupae (Ibrahim et al. 2013). Ibrahim et al. (2013) found that the optimum performance of the two species of bagworm, namely *P. pendula* and *M. plana,* can be expected to occur in the range of 30°C to 35°C.

Hughes (2000) stated that changes in variables such as increasing the average temperature and modified patterns of precipitation will directly and indirectly affect specific species, resulting in changes to the composition and organization of biotic communities. During this phase, the neonate begins to consume food and construct a portable bag made of silk, using the foliage of the oil palm leaflets (Kok et al. 2011). Therefore, the silk possesses sufficient strength due to its composition of numerous leaf fragments (Cheong et al. 2010; Kono et al. 2019). Temperature and light have been found to increase the activity and spread of *Luffia ferchaultella*, a type of bagworm insect. These insects tend to stay in bark fissures when the temperature is below 4°C and do not appear to feed when the temperature drops below 34°C (McDonogh 1939).

However, Figure 3 demonstrate a negative non-significant correlation between humidity and the population of *M. plana* for early and late stages, whereby P is 0.062 (r=- 0.242) and 0.074 (r=- 0.237), respectively. Study by Kumar and Singh (2023) showed the similar result on which the negative correlation also has been found not affected the relative abundance of *Amrasca biguttula biguttula* on french bean. Increased humidity negatively impacts the survival of bagworms, with a critical range of humidity between 72.1% to 79.2% (Nur Robaatul Adhawiyah et al. 2023). An increase in temperature will cause a drop in relative humidity, resulting in drier air. Conversely, a fall in temperature will cause an increase in relative humidity, leading to wetter air. Studies on geometrid moths have determined that humidity is a crucial climatic factor (Intachat et al. 2001; Brehm et al. 2007). Regarding leafhopper density counts, there was a positive correlation between the highest temperature and the number of hoppers, but the relative humidity did not have a significant effect (Mahmood et al. 2002).

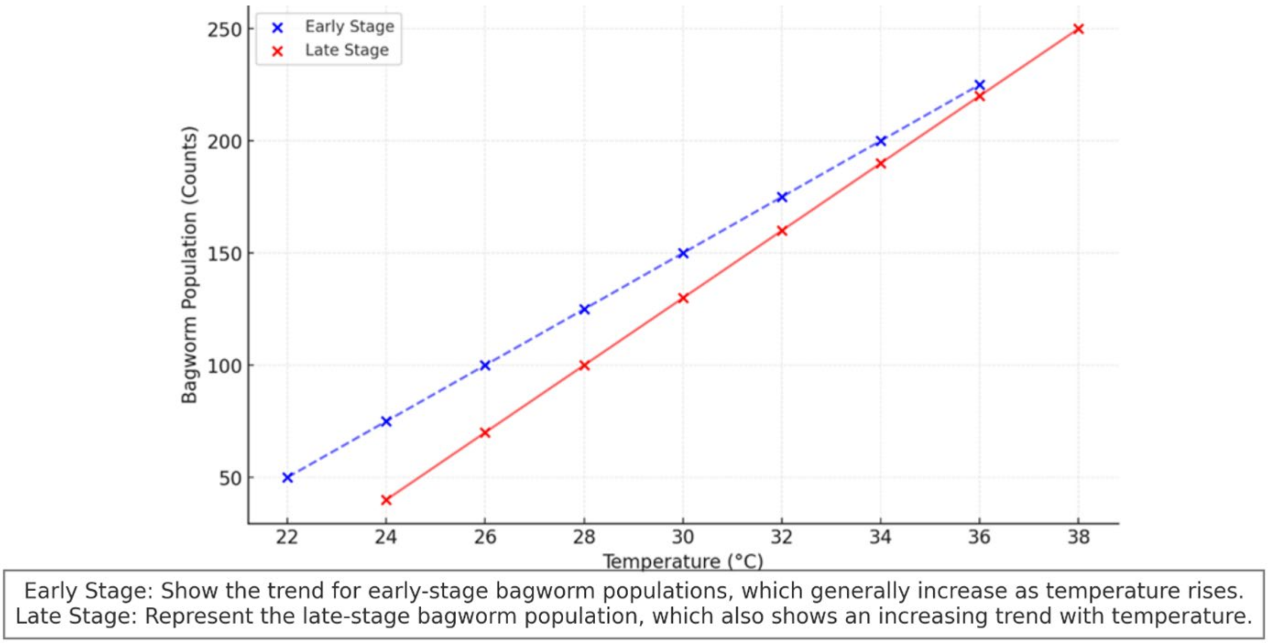
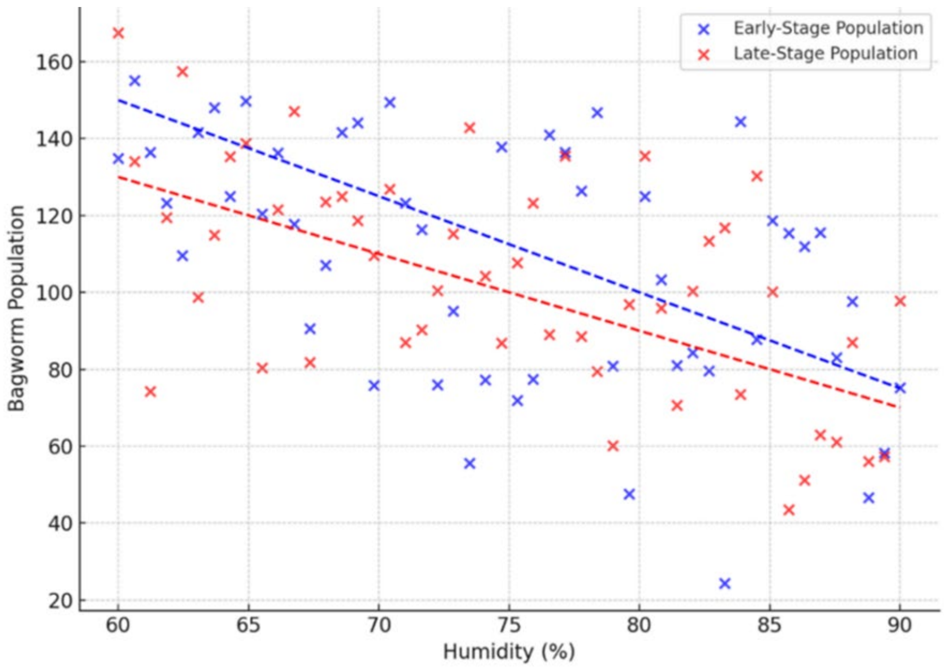



Figure 4. The relationship between temperature (°C) and bagworm population (counts), comparing the early-stage and late-stage populations




Early-Stage Population: Decreases as humidity increases, with a clear downward trend.
Late-Stage Population: Also decreases with increasing humidity, but at a slower rate than the early stage.

Figure 5. The relationship between humidity (%) and bagworm population (counts), comparing the early-stage and late-stage populations

The average rainfall for the early stage of bagworm observed was 229.4 mm, with a maximum rainfall of 576 mm. Initially, there was a weak positive relationship between *M. plana* population and rainfall where (P = 0.124, r = 0.250). A slight positive link between the population of *M. plana* and rainfall is also found during the late stage (Figure 6) where the weak positive correlation is demonstrated in Table 1, whereby P= 0.338 (r=0.211). The mean rainfall for the late stage of bagworm was 225.9 mm, with a maximum rainfall of 576 mm (Table 1). The high rainfall on the other hand, shows a higher population of bagworm infestation.

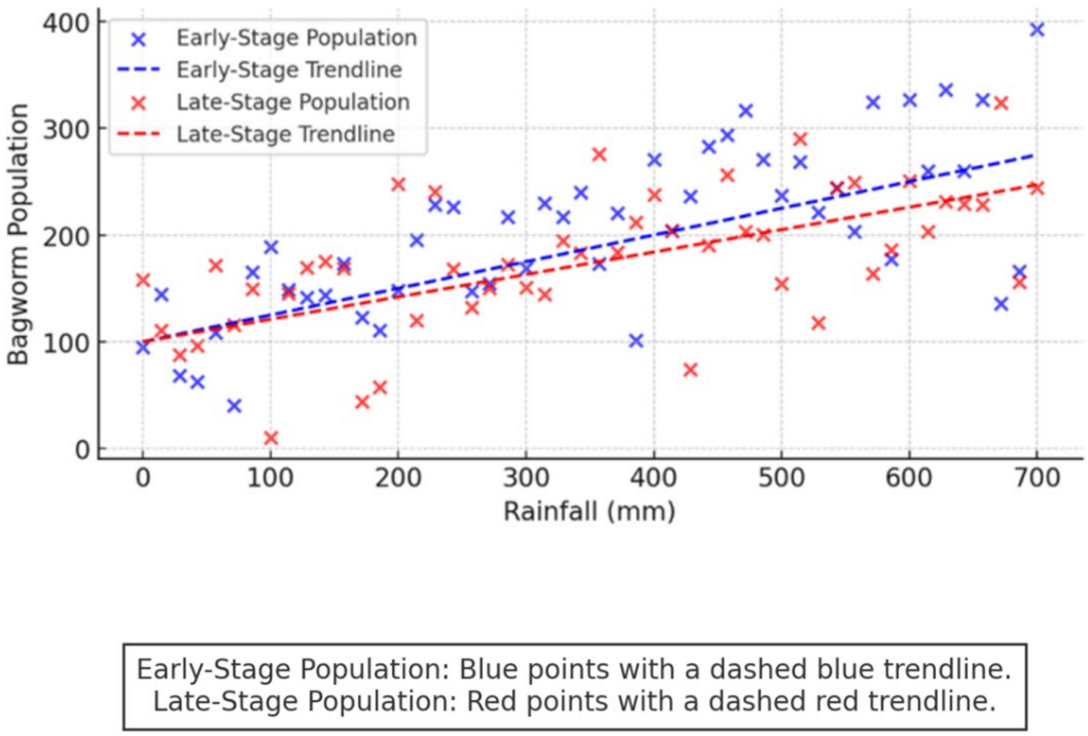



Figure 6. The relationship between rainfall (mm) and bagworm population (counts), comparing the early-stage and late-stage populations

Figure 6illustrates the relationship between rainfall and bagworm (*Metisa plana*) populations at early and late developmental stages. Both stages exhibit a weak positive correlation with rainfall, indicating that as rainfall increases, bagworm populations tend to rise slightly. The early-stage population shows a correlation coefficient (r=0.250) with a p-value of 0.124, suggesting a non-significant relationship. In contrast, the late-stage population has a correlation coefficient (r=0.211) with a p-value of 0.038, indicating a statistically significant relationship. These findings align with recent studies examining environmental factors affecting bagworm populations. For instance, a study by Nur Robaatul Adhawiyah et al. (2023) found that temperature and rainfall had minimal effects on bagworm populations, whereas relative humidity showed a negative correlation. Similarly, research by Mahadi et al. (2012) reported a negative weak correlation between bagworm populations and monthly rainfall, concluding no significant relationship. The weak positive correlations observed in the graph suggest that while rainfall may influence bagworm populations, it is not the sole determinant. Other environmental factors such as temperature, humidity, and the presence of natural enemies, also play significant roles in shaping bagworm population dynamics. Therefore, integrated pest management strategies should consider multiple environmental factors to effectively control bagworm infestations. The shape of the interconnected frond canopy's covering, which protects the bagworm from direct sunlight and heavy rainfall, could potentially serve as an example of such a characteristic. Bagworms were observed taking refuge under oil palm leaflets to seek protection from rainfall (Nor Ahya et al. 2012). This result is similar to behaviour of jassid nymphs which exhibit a preference for inhabiting the lower surface of leaves, making it improbable for direct rainfall to significantly affect them. The tendency of jassid nymphs to move towards the midrib when the plant is disturbed may also serve as a means of sheltering them from rain (Mahmood et al. 2015). Recent studies have examined the impact of rainfall on oil palm bagworm populations, suggesting that wet conditions may render leaves unsuitable for feeding, promote entomopathogenic activity, and reduce dispersal. For instance, research by Cheong et al. (2010) observed that heavy rainfall can wash off bagworm larvae from leaves, leading to increased mortality. Additionally, a study by Mahadi et al. (2012) found that high rainfall levels enhance the activity of entomopathogenic fungi, which infect and kill bagworms, thereby reducing their populations. These findings align with earlier conjectures by Syed and Shah (1977) regarding the adverse effects of rain on bagworm populations. Floods, the extreme outcome of rain, have also been surmised to predispose outbreaks by killing natural-encouraging ground vegetation. Ibrahim et al. (2021) mentioned in his study that the right combination of drought and rainfall probably requires a dramatic encouragement of bagworm populations. The inability of this to be attained during many dry weather episodes has probably led to the comment that drought being an unreliable prediction of outbreaks.

## CONCLUSION

The environmental circumstances can facilitate early monitoring and planning for bagworms, benefiting oil palm smallholders and plantations and enabling mitigation of the escalating the pandemic. In this investigation, all environmental parameters were precisely recorded. It was found that temperature, rainfall, and humidity significantly impact the life cycle and population dynamics of bagworms particularly in the context of unexpected and inconsistent climates. Abiotic factors influence the population dynamics of bagworms since they can affect the reproductive capacity and spatial spread of these insects. To reduce the bagworm infestation, management might take steps to control the larvae during the early instar stages. Conducting more research on the relationship between environmental conditions, host plants, and parasitoids will be beneficial in improving our understanding of the elements that contribute to the extensive bug epidemic and its synchronisation throughout large areas of Malaysia. However, the utilisation of strong quantitative data is necessary to improve the accuracy of predictions.

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## AUTHORS DECLARATIONS

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**Conflict of Interest**
The authors declare that they have no conflict of interest.

**Ethics Declarations**
No ethical issue required for this research.

**Data Availability Statement**
My manuscript has no associated data.

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