SHORT COMMUNICATION

IMPACT OF ENVIRONMENTAL FACTORS ON THE LARVAL POPULATION OF BAGWORM, *Metisa plana* WALKER (LEPIDOPTERA: PSYCHIDAE) IN OIL PALM SMALLHOLDINGS

Nur Robaatul Adhawiyah Mohd Ali Napiah*, Noorhazwani Kamarudin, Shamsilawani Ahmad Bakeri, Nurhafizhoh Zainuddin, Mohd Fahmi Keni, & Mohamed Mazmira Mohd Masri
Malaysian Palm Oil Board,
6 Persiaran Institusi,
Bandar Baru Bangi,
43000 Kajang, Selangor, Malaysia
Corresponding author: adhawiyahman@mpob.gov.my*

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ABSTRACT

Infestations and outbreaks of bagworms, *Metisa plana* Walker (Lepidoptera:Psychidae) have been reported primarily in Peninsular Malaysia for many years. Bagworm infestation is a significant problem primarily due to the mismanagement and lack of proper monitoring in the field, which later affected the yield and profit loss, especially among smallholders. Understanding the impact of environmental conditions on bagworms may assist in a more proper pest control strategy. Changes in environmental conditions have the potential to interrupt the bagworm's life cycle. This study investigated the effects of temperature, humidity, and rainfall on the bagworm population in selected smallholding oil planted areas in Johor. Anemometer was used to collect the data of temperature and humidity while the collection of rainfall was taken from Meteorology Station. The results showed that temperature (r= 0.211) and rainfall (r= 0.108) have minimal effects on the bagworm population, recording positive relationships with *Metisa plana*. Relative humidity (r= -0.203), however, showed a negative correlation with *M. plana.* The findings suggested that temperature and rainfall may affect bagworm populations, but a long-term study is required to comprehend this impact fully. An improve scientific approach should be used in future research along with suitable Integrated Environmental Pest Management (IEPM) techniques, monitoring of the climate and pests, and the use of modelling tools as mitigation strategies to determine the effects of environmental factors in bagworms.

Keywords: *Metisa plana*, abiotic factors, temperature, relative humidity, precipitation

ABSTRAK

Serangan dan letusan oleh ulat bungkus, *Metisa plana* Walker (Lepidoptera: Psychidae) telah dilaporkan terutamanya di Semenanjung Malaysia selama bertahun-tahun. Serangan ulat bungkus merupakan masalah yang amat serius disebabkan oleh sistem pengurusan yang lemah dan kurangnya pemantauan yang baik di ladang. Seterusnya menjejaskan hasil dan keuntungan dalam industri sawit, terutamanya kawasan penanaman dalam kalangan pekebun kecil. Pemahaman tentang kesan keadaan persekitaran terhadap ulat bungkus boleh membantu dalam strategi kawalan perosak yang lebih tepat. Perubahan dalam keadaan persekitaran berpotensi untuk mengganggu kitaran hidup ulat bungkus. Kajian ini mengkaji kesan suhu, kelembapan dan hujan ke atas populasi ulat bungkus di kebun kecil terpilih yang terletak di Johor. Anemometer digunakan bagi mengumpul data suhu dan kelembapan manakala bacaan kutipan hujan diambil dari Stesen Meteorologi. Hasil kajian menunjukkan bahawa suhu (r= 0.211) dan hujan (r= 0.108) mempunyai kesan yang minimum ke atas populasi ulat bungkus, yang mana hasil kajian merekodkan kolerasi positif dengan *M. plana.* Kelembapan relatif (r= -0.203), bagaimanapun, menunjukkan korelasi negatif dengan *M. plana*. Hasil kajian mendapati bahawa suhu dan hujan mempengaruhi populasi ulat bungkus, tetapi kajian jangka panjang diperlukan untuk memahami kesan ini sepenuhnya. Pendekatan saintifik harus digunakan dalam penyelidikan lanjut bersama-sama dengan teknik Pengurusan Persekitaran Perosak Bersepadu (PPPB) yang diubah suai, pemantauan iklim dan perosak, dan penggunaan alat pemodelan sebagai strategi mitigasi untuk menentukan kesan faktor persekitaran dalam ulat bungkus.

Kata kunci: *Metisa plana*, faktor abiotik, suhu, kelembapan relatif, hujan

Bagworm *Metisa plana* (Lepidoptera: Psychidae) is a major pest of oil palm and can potentially cause a 44% loss of crops in an outbreak. According to several reports, *M. plana* is the most prevalent oil palm pest in Peninsular Malaysia (Badrulisham et al. 2021; Mazmira et al. 2022; Norman et al. 1994; Norman & Basri 2007; Ramlah et al. 2007a; 2007b; Sakaran 1970). Smallholders reported that bagworm had affected more than 24,385.9 hectares (ha) in 2014. (Noorhazwani et al. 2017). Destruction of oil palm trees by bagworms can reduce yield by as much as 10 tons of fresh fruit bunch (FFB) per acre and can destroy as much as 50% of the trees (Wood et al. 1972). Malaysia and Indonesia, are among the world's leading palm oil suppliers, accounting for 85% of total production from these two countries (Hangga 2018; Serina 2020). The demand for palm oil has increased by 2.3 million tonnes annually during the past ten years. The country's oil palm business is experiencing financial losses due to the rapid development of numerous pests that threaten palm oil production due to the rise in demand for palm oil (Kok et al. 2012; Mazmira et al. 2022; Tan et al. 2008; Yap 2005).

The life cycle of the bagworm, instars, and egg production varied depending on the types of species. *Metisa plana*'s life cycle lasts around three months, *Pteroma pendula* for about forty days and *Mahasena corbetti* for about four months (Wood & Norman 2019). In a study on the impacts of various temperatures, Yusof et al. (2013) discovered a time frame for a life cycle for *M. plana* and *P. pendula* in 30°C treatment. When the temperature drops below 15°C, the life cycle length lengthens to 35°C (Wood & Norman 2019). While Wood (1968) discovered 3000 eggs for *M. corbetti* and Syed (1970) discovered a mean of roughly 2000 eggs for *M. corbetti*. However, any population study may have a wider variation. Basri and Kevan (1995) reported that laboratory-reared individuals typically produce more eggs than those gathered from the field. Field-reared females of both *M. plana* (overall mean of 74 vs 83 days) and *P. pendula* (overall mean of 50 against 57 days) developed more quickly over time than full-grown females reared in a lab (Ho et al. 2010).

Ecological, biological, and chemical measures were used to manage bagworms in oil palm plantations, although early infestation diagnosis and periodical pest counts are of the utmost importance. Recently, the control measures have demonstrated cost-effectiveness in resolving numerous outbreaks. It would be realistic to control bagworm outbreaks by changing the environment to promote conservation and increase the number of natural enemies (Halim et al. 2018; Ho et al. 2011; Siti Nurulhidayah & Norman 2016). Planting beneficial plants and releasing predator species like *Sycanus dichotomus* into the wild can help avoid or decrease outbreaks and lessen the need for chemical pesticides (Siti Nurulhidayah & Norman 2016). In addition, several natural enemies have been used in oil palm plantations to suppress bagworms, including *Cosmelestes picticeps* (Hemiptera: Reduviidae), *Cotesia* (*Apanteles*), and *Dolichodenidea metesae* (Hymenoptera: Braconidae) (Cheong et al. 2010; Fuat et al. 2022). Adoption has increased in recent years of *Bacillus thuringiensis* as one technique to reduce bagworm infection epidemics (Shahir et al. 2013). Two weekly censuses were conducted to monitor the pest population and foliage damage to determine the necessity and optimal time to implement control measures.

It is typical of insects that have evolved to endure brief durations of poor, non-lethal conditions (Sandra et al. 2021). Insects that endure extreme conditions for several months go into a developmental stop called diapause. Environmental cues (usually the photoperiod) that operate before the onset of unfavourable conditions cause diapause. Low temperatures may make diapause brought on by a brief photoperiod more common. A few species housed in permanent darkness can go into diapause as a result of daily temperature variations, known as the thermo-period. Once diapause has been created, it must last for a predetermined amount of time, usually months, before neuro-hormonal regulation returns to the pattern favouring growth and reproduction. Predictable environments allow for definite life cycles, such as diapause in the winter and development in the summer. However, individuals can follow different life-cycle trajectories in many species from erratic settings. As the climate changed, insects' physiology, phenology, and distribution have all been affected (Harrington et al. 2001; Hughes 2000).

Physiological processes may accelerate under warmer settings, faster growth, more generations in a single lifetime season, increased and decreased mobility. Warmer temperatures may allow for more time to be spent outdoors. Activities at the beginning and end of the season aid in the elimination of pests and coordinate in preserving the environment egg and bud burst in spring. Warmer temperatures may also boost the poleward range, low temperatures are presently limiting the expansion of species or heights (Harrington et al. 2001; Van Asch & Visser 2007).

Environmental conditions may impact the life-cycles of bagworms. Nor Ahya et al. (2012) and Enting and Latip (2021) claim that the presence of numerous bagworm larvae that are being washed away by rainfall during the various rains that occur each month may have an effect on the population of bagworms. *Pteroma pendula* and *M. plana* demonstrated the general trend of insects, which indicated that development durations shortened as temperatures rose until the peak was achieved (Assante et al. 1991). For all life stages, a temperature of 35°C generally yielded the quickest developmental durations, whereas 30°C often yielded the highest survival rates. The bagworm, *Thyridopteryx ephemeraeformis*, thrived in hotter-than-air environments, the severity of which depended on the host plant type and the size of the bags used (Barbosa et al. 1983; Smith & Barrows 1991). Morris (1957) showed that population dynamics entails tracking population growth and decline across time and digging into the root reasons of environmental shifts. The aim of this study was to investigate the relationship between environmental factors such as temperature, humidity and rainfall towards the population of bagworm, *Metisa plana*.

A pre-census of bagworms was performed to count and record the initial population of bagworms. One percent of the contaminated area was enumerated by removing one palm from every ten palms in every ten rows. Palm tree was cut down and examined for signs of recent damage to determine the number of larvae and pupae on both sides of frond number 17 from the centre of the canopy. The study site was selected in area in Johor as Johor one of the most infested area of *M.plana*. The study site was comprised with about 13 of smallholder-owned oil palm lands infested with the bagworm *M. plana* (Lepidoptera: Psychidae) in Batu Pahat, Kluang, and Segamat, Johor, Malaysia. The infested area was covered by oil palm aged between 10-15 years old. The time frame in taken the data for this study was taken from 2018-2021 (3 years). About 60 samplings effort have been taken in the infested area.

Environmental changes such as temperature (°C), rainfall and humidity (%RH) were recorded during the sampling period. The average rain data were requested at Meteorology Station in Batu Pahat, Kluang and Segamat in Johor, Malaysia monthly for three years. The effect of temperature and humidity were collected using an anemometer every 1-2 weeks monthly for 3 years (2018-2019 and 2021). Data on the population of bagworms against environmental factors (temperature, rainfall and humidity) was analysed using the regression analysis (Sigma-plot version 14). Correlation analysis between the effect of environment factors (temperature, humidity and rainfall) and bagworm population was performed by using Pearson Correlation analysis at 0.05 significance level.

The mean result of temperature for this study was 29.5°C where the maximum and minimum temperature recorded was 35.1°C and 24.4°C (Table 1). The higher the temperature showed the higher population of *M. plana* with range of temperature between 29°C to 31°C (Table 2). The outcome revealed a weak correlation for all weather parameters (Figure 1). The link between the *M. plana* population and temperature is positively skewed and correlated, whereby P is 0.203 (r=0.211) as shown in Table 3. The temperature was commonly observed to affect the growth of the larvae and pupae, as well as the fecundity of the female gypsy moth (Alalouni et al. 2013). Andresen et al. (2001) informs that further information about egg masses could affect by winter and spring temperatures. According to Hughes (2000), factors like rising mean temperatures and shifting precipitation patterns would directly and indirectly affect certain species, changing the make-up and structure of biotic communities. On the other hand, Choi (2008) reported that the key indicator for predicting the emergence of adult moths in a temperate forest in southern Korea was mean temperature.

Table 1. Population dynamics of bagworm larvae vs. weather parameters for Johor during 2018-2019

Date of Sampling	Location	Temperature ^{0}C	Relative Humidity %	Rainfall mm	No. of Bagworm larvae
2/10/2018	Johor: Batu Pahat, Parit Jayus	25.7	81.4	192.2	56
9/10/2018		28.3	79.6	192.2	8
7/11/2018		26.3	76.2	152	21

14/11/2018		29.4	72.4	152	21
21/11/2018		26.5	80.2	152	17
28/11/2018		28.4	77.2	152	11
5/12/2018		26.2	79.4	158.4	8
12/12/2018		27.5	77.3	158.4	5
3/10/2018	Johor: Batu Pahat, Sri Jagung	28.1	75.4	192.2	36
24/10/2018		34.4	71.4	192.2	12
8/11/2018	Johor: Batu Pahat,Temehel	26.7	83.6	152	1
8/11/2018	Johor: Batu Pahat,	30.4	85.2	152	1
9/11/2018	Johor: Batu Pahat, Sg Purun	26.2	75.4	152	1
7/12/2018	Johor: Batu Pahat, En. Eng Kim San	24.4	79.2	158.4	12
13/12/2018		27.4	82.4	158.4	12
27/12/2018	Johor: Batu Pahat, En. Ng Paloh	29.4	83.2	158.4	228
28/12/2018	Johor: Batu Pahat, Sri Dayong	28.2	78.4	158.4	94
7/3/2019	Johor: Batu Pahat, Sri Jagung	28.5	70.1	61.2	2
14/5/2019	Johor: Batu Pahat, Temehel	32.6	80.3	141	68
11/6/2019		30.1	81.1	210.2	10
12/6/2019		29.1	83	210.2	10
17/4/2019	Johor: Batu Pahat, Ngamarto	31.2	80.4	254.2	103
16/5/2019		32.2	74.7	141	7
28/5/2019		32.6	77.7	141	7
2/5/2019	Johor: Segamat, HT Alliance Estate	30.2	73.8	154.9	18
29/5/2019		32.7	70.9	154.9	54
28/2/2019	Johor: Batu Pahat, En. Eng Kim San	30.2	77.4	49.7	23
12/3/2019		31.7	68.5	61.2	143
21/3/2019		28.2	77.4	61.2	15
27/3/2019		32.1	67.1	61.2	112
4/4/2019		25.5	83.2	254.2	85
9/4/2019		30.8	69.5	254.2	13
16/4/2019		31.6	74.6	254.2	7
2/1/2019	Johor: Batu Pahat, En. Ng Paloh	28.2	73.3	47.6	198
17/1/2019		30.1	78.2	47.6	38
7/2/2019		35.1	74.3	49.7	50
11/2/2019		32.2	80.9	49.7	71
5/3/2019		29.7	72.5	61.2	30
28/3/2019		30.8	61.2	61.2	15
2/4/2019		31.3	69.4	254.2	15
23/4/2019		28.9	79.1	254.2	24
3/1/2019	Johor: Batu Pahat, Sri Dayong	29.3	80.4	47.6	101
4/1/2019		30.2	79.3	47.6	101
25/1/2019		29.5	76.4	47.6	41
1/2/2019		29.5	72.6	49.7	31
8/2/2019		31.2	74.3	49.7	29

12/2/2019		31.2	69.7	49.7	23
21/2/2019		28.2	67.7	49.7	17
26/2/2019		31.4	69.7	49.7	13
14/3/2019		24.7	85.1	61.2	18
19/3/2019		31.3	64.8	61.2	15
10/4/2019		31.2	76.3	254.2	21
16/1/2019	Johor: Segamat, Kg Orang Asli Bekok	27.5	79.3	150.5	87
6/3/2019		28.4	69.3	135.9	225
15/5/2019		31	75	154.9	86
31/1/2019	Johor: Batu Pahat, Sri Jagung	29.5	72.2	47.6	31
8/2/2019		30.1	74.2	49.7	139
8/3/2019	Johor: Batu Pahat, Ng Paloh	28.5	70.1	61.2	2
16/5/2019	Johor: Batu Pahat, Sg Renek	31.1	77.9	141	1
24/5/2019	Johor: Batu Pahat, Parit iImail C&D	29.5	72.6	141	9

Table 2. Population dynamics of bagworm larvae vs. weather parameters for Johor during 2021

Date of Sampling	**Location**	**Temperature ^{0}C**	**Relative Humidity %**	**Rainfall mm**	**No. of Bagworm larva**
5/1/2021	Johor: Pagoh, Segamat	26.4	78	0	53
23/3/2021		26.4	78	0	31
3/8/2021		29	73.8	181.6	141
25/8/2021		29	73.8	181.6	20
1/9/2021		28.4	64.8	306.8	20
14/9/2021		29.2	65.8	306.8	0
5/10/2021		28.4	64.8	109	63
12/10/2021		28.2	65.3	109	43
20/10/2021		28.1	74.3	109	36
4/8/2021		30.6	75	181.6	37
2/3/2021	Johor: Batu Pahat, Sri Dayong	28.3	70.1	337.6	273
30/3/2021		28.7	70.4	337.6	7
25/3/2021		28.5	71.3	337.6	10
30/6/2021		32.7	65.7	222	74
28/7/2021		33	71	101	28
2/3/2021		30.8	65.3	337.6	317
30/3/2021		29.2	66.3	337.6	18
8/4/2021		30.8	65.3	181.4	70
26/5/2021		30.3	74.6	197	15
29/6/2021		30.2	68.4	222	69
3/3/2021		30.8	78.4	337.6	109
7/4/2021		28.2	78.4	181.4	24
27/5/2021		30.3	75.9	197	9
1/7/2021		30.1	72.8	101	76
12/8/2021		30.1	74.8	335.6	2
26/10/2021		28.1	74.3	124.6	60
24/3/2021		26.8	73.3	337.6	257
27/4/2021		26.8	73.3	181.4	31

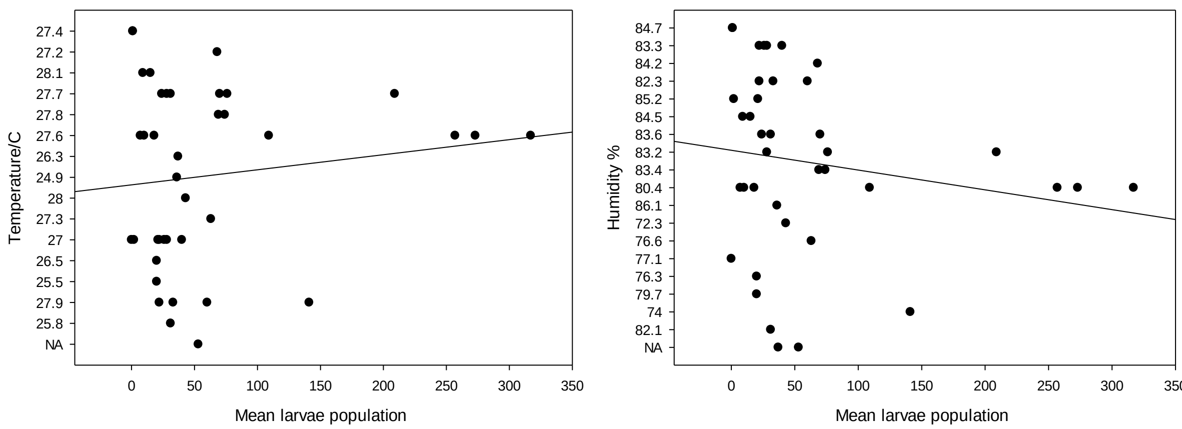
27/7/2021		33.8	64.9	101	209
10/8/2021		32.8	65.9	335.6	21
7/9/2021		33.3	66.5	447.4	68
6/10/2021		30.5	68.2	124.6	33
21/10/2021		27.4	79.2	124.6	22
6/4/2021	Johor: Kluang, Sedenak	28.3	70.1	389.8	40
13/4/2021	Johor: Kluang,	28.2	70.4	389.8	28
14/4/2021	Layang-layang	29.3	72.1	389.8	26
15/4/2021		28	70.2	389.8	22
5/5/2021	Johor: Segamat, Bekok	29.7	72.2	197	1
11/5/2021		31.3	70.5	197	1

Table 3. Correlation of bagworms with weather parameters in smallholdings in Johor

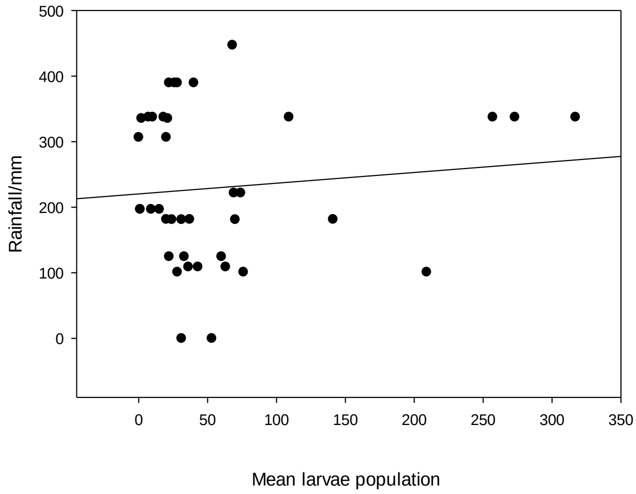
	Correlation with Weather Parameters (α = 0.05)		
	Temperature	**Rainfall**	**Humidity**
Bagworms	0.203 (0.211)	0.513 (0.108)	0.0227 (-0.203)

Description: Number in brackets = correlation coefficient value (r). The correlation column shows the probability (P) value;
* = significant at α= 0.05.

On the other hand, it was found that the mean rainfall observed was 168.7 mm with the maximum rainfall recorded at 389.8 mm in Table 1. In addition, the lower population of bagworm was influenced by high rainfall with a range of 192.3 mm to 389.8 mm (Table 2). A weak positive association between the population of *M. plana* and rainfall is also seen (Figure 1). The weak positive correlation is shown in Table 3, whereby P=0.513 (r=0.108). However, research by Cheong et al. (2010); Nor Ahya et al. (2012) and Enting & Latip (2021) suggested that *P. pendula* and rainfall were not found to be significantly correlated. Therefore, there may be other variables that caused the variation in bagworm numbers. The form of the connected frond canopy's cover, which shields the bagworm from direct sunlight and heavy precipitation, might represent one such feature. Bagworms were seen resting beneath oil palm leaflets, which provided shelter from raindrops. The polyphagous characteristic of *P. pendula*, the inadequate management of bagworm infestations by smallholders due to the high expense of insecticides, and the mono-cropping method in oil palm farms are all likely causes of bagworm infestations (Cheong et al. 2010; Enting & Latip (2021).



(a) (b)



(c)

Figure 1. A. Correlation between temperature and population of *M. plana* B. Correlation between rainfall and population of *M. plana* C. Correlation between relative humidity and population of *M. plana*

The mean for humidity in this study observed was 73.9 where the maximum and minimum of humidity recorded was 85.2(%) and 61.2(%) in Table 1. The higher humidity observed the low population of bagworm survival with range of humidity between 72.1% to 79.2% (Table 2). Figure 1(c) demonstrates a slight negative connection between humidity and the population of *M. plana* whereby P is 0.0227 (r=-0.203) as shown in Table 3. When it comes to leafhopper density counts, the maximum temperature had a positive link with the number of hoppers, but neither the relative humidity nor rainfall had a significant impact. Jassid nymphs prefer to live on the underside of leaves; and thus, direct rain drop action is unlikely to have a substantial impact. The inclination of jassid nymphs to go towards the midrib when the plant is disturbed may also help protect them from rain. Cotton jassid may be efficiently controlled by mud splashed on the leaf undersides following heavy rainfall, according to a study in Sudan (Hanna 1960). According to Mabbett et al. (1984), in theory, the jassid nymphs on the lower leaves may be reduced by splashing mud on them, however this was not included in the sampling. It was found that the number of jassid nymphs was not significantly affected by rain in the leaf-active zone.

The environmental conditions may aid oil palm smallholders and estates in monitoring and planning for bagworm control earlier, before the outbreak becomes more severe. Thus, environmental factors were crucial in regulating the population of bagworms, as they may influence the generation and spread of bagworms. Research explored the effect of a variety of rare biotic and abiotic variables on *M. plana* dynamics, with a focus on the insect's and its host plant's phenology. Quantitative data crucial for predicting the population dynamics of this critical leaf-eating insect and mitigating its effect is limited, despite decades of study on the ecology, population dynamics, and relevance of natural enemies. More research into the relationship between environmental conditions, host plants, and parasitoids would be useful in gaining a better understanding of the causes of this insect outbreak and its synchronisation across extensive areas of Malaysia.

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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 data related to Rahayu et al. research on actinobacterial morphology data

Authors' Contributions
LF and NJ conceived this research and designed experiments; LF, NJ, and YY participated in the design and interpretation of the data; LF, NJ, and YY performed experiments and analysis: LF, NJ, and YY wrote the paper and participated in the revisions of it. All authors read and approved the final manuscript. All authors read and approved the final manuscript

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