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RESEARCH PAPER

Evaluation of Bagworm, *Metisa plana* (Lepidoptera: Psychidae) Infestation and Beneficial Parasitoid in an Oil Palm Plantation, Perak, Malaysia

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Abstract

Oil palm (*Elaeis guineensis*) planting is one of the economic pillars of countries rich in biodiversity in tropical regions. However, pest and disease are the most serious limitation of oil palm production. Bagworm, *Metisa plana* (Lepidoptera: Psychidae) is considered the most destructive pest in the oil palm plantation in Malaysia, which could cause high yield losses up to 43% over two years after a serious infestation and become a primary concern among stakeholders. Conventional excessive use of pesticides causes serious environmental pollutions and damage to non-target organisms. Thus, biological control can be reduced the pest populations safely and efficiently by beneficial insects such as parasitoids. This study aims to (i) evaluate the bagworm infestation in an oil palm plantation, Perak, Malaysia; (ii) determine the impact and damage of the bagworm stages on the oil palm plantation, and (iii) evaluate the parasitoid in such areas. A total of 57 palm trees have been systematically selected. Bagworm and parasitoid samples were collected in two stages at Felda Gunung Besout 2, Perak, Malaysia. Bagworm infestation severity was performed based on the severity scale of bagworm damage symptoms. The results showed that the incidence rates of oil palm trees are concerned 50.9%, 31.6%, 4%, 3.5% were low, moderate, high, and no incidence, respectively. Bagworm stages 1, 5, 6, and 7 are significantly impacted on the oil palm incidences and stage seven is the most impacted one; followed by stages 1, 6 and 5. Several parasitoids have been found; the highest one is Eulophidae: *Tetrastichus s planipennisi.*

Keywords: Oil palm; Bagworm; Biological control; Natural enemy

INTRODUCTION

Oil palm is one of the very economically valuable oil-producing plants especially in Malaysia which considered the second larger producer worldwide (Al-Obaidi et al., 2016). During the increasing rate of oil palm expansion, insect pest infestation (e.g. bagworms) has become a primary concern among stakeholders (e.g. food manufacturers, consumers, trade associations, non-governmental organisations, academics, and finance institution) (Ahmad et al., 2020; Jamian et al., 2017). Therefore, the production of fruits which is a source of oil reduced, affecting the oil quality and quantity (Barcelos et al., 2015). To overcome this great damage caused by the bagworms, farmers used common practices to eliminate bagworms using chemical treatment, which causes serious environmental pollution (Zhou et al., 2014). In oil palm plantation, yield can be severely affected by pests that compete against the palm for nutrients, infect, or damage the palm (Verheye, 2010). Bagworm (Lepidoptera: Psychidae) is one of the important leaf-eating pests of oil palm in Malaysia and Indonesia (Hisham, 2012). Infestations and outbreaks of bagworm have occurred in Malaysia for over five decades. It continues to be a problem today even though the availability of effective control measures such as chemical ones (Loong & Chong, 2012). Moderate defoliation of about 10%-13% may cause a crop loss and decrease in the production of oil palm about 33%-40% (Hanysyam et al., 2013). Rising palm oil prices in 2016, made commodities less competitive against alternative vegetable oils.

The pesticides applied to agricultural lands affect non-target organisms and contaminate soil and water media (Margni et al., 2002). Control of bagworms by insecticides, particularly in the later larval stages considered not successful because it is not as effective when the bagworm close their bags (Rhainds & Sadof, 2009). Moreover, the height of the plant is the problem for spraying insecticides as they attain more than 20 feet height within 15 years in irrigated plantations, though root feeding and stem injection are being practised (Kalidas, 2012). Also, the use of tractor-drawn air-blast sprayers, which would theoretically be the most effective means of control, is precluded by the uneven terrain, swamps and large boulders characteristic of the region. Besides, shoulder-mounted mist-blowers give adequate coverage for only of palms under six years old (Halim et al., 2017).

The biological control of bagworm populations to the maintenance of local habitat complexity and farmland biodiversity is the direction for bagworm control (Jamian et al., 2017). The parasitoids have been widely used in biological control programs and it approved to be a good weapon to control Lepidoptera pests (De Oliveira et al., 2017). Due to it has a high capacity of parasitism. There are variations in the parasitoid and bagworm types used in Malaysia. According to the biological control and parasitoid benefits, the present study has been evaluated the availability of the parasitoid in oil palm Perak plantation to provide clear guidelines and recommendations about the available natural enemies for other research that aim to control the oil palm plantation biologically to reduce or eliminate Bagworm on oil palm Perak plantations. This research aims to improve the quality of palm oil and production by evaluating bagworm infestation in oil palm plantation. The research objectives were to evaluate the bagworm infestation in oil palm plantation and to determine the impact of the bagworm stages and their damage on the infestation of oil palm plantation in Perak.

RESEARCH METHODOLOGY

Location

The bagworm infestation was evaluated at an oil palm plantation in the Felda Gunung Besout 2, Perak, Malaysia (3°50'15.3"N 101°17'32.9"E) in a growing season in 2018. This location had an average temperature of 28C° and a dew point of 25 ºC. The total acreage of the plantation is about 892 hectares and estimation for oil palm planting is around 647 hectares (Figures 1 and 2). The age of oil palm was 15 years old.

Figure 1. Sampling site.

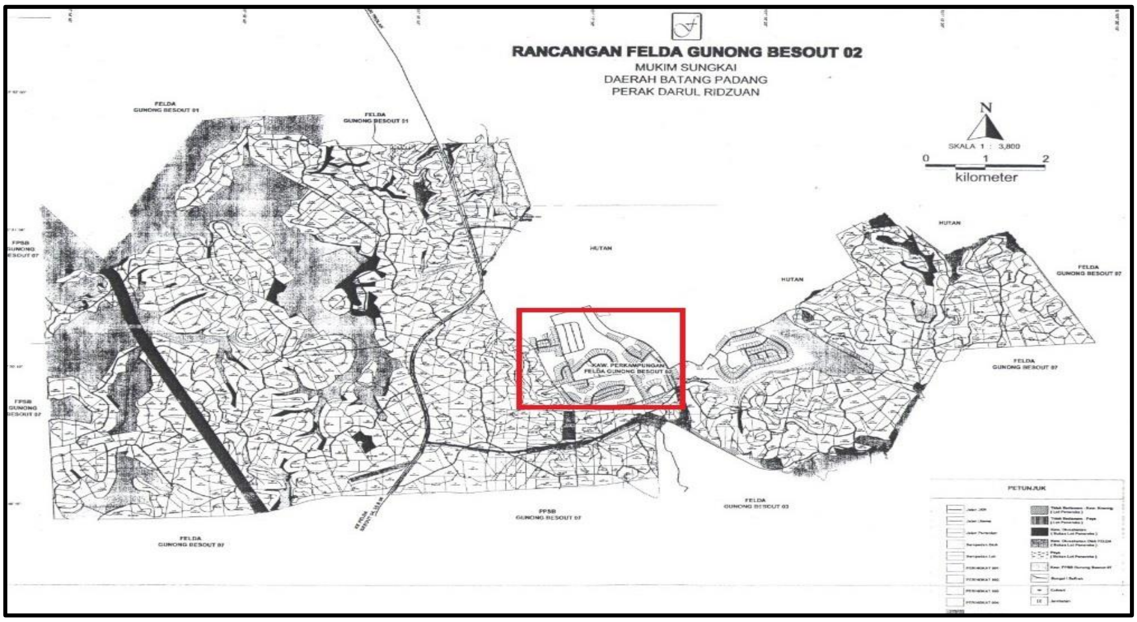

Figure 2. Oil palm plantation plan and coordination.

Research Method Design

Leaf samples have been collected using a systematic sampling method (Sulai et al., 2015). Samples have been placed in a grid frame with points (Figure 3A). From the sampling frame, the selected sites for the study consisted predominantly of oil palm, carried live bagworm larvae and parasitoid. The sampling site was selected according to the area which had an incidence of bagworms. Then, gridding the sampling frame in Zic-Zac design from starter point until the end is done (Figure 3B). These palms have been marked with plastic tape. The approximate distance is three trees from each other. The coordinates of each point have been taken with the Global Positioning System (GPS).

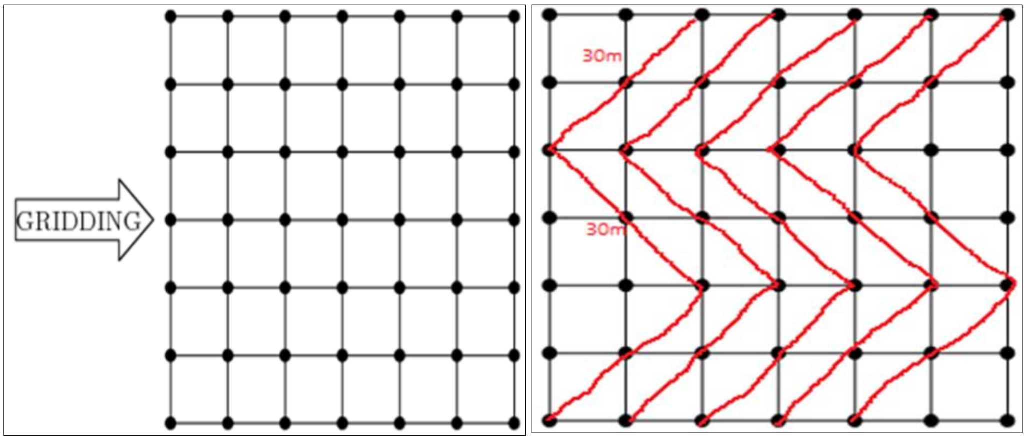

Figure 3A Figure 3B

Figure 3. Systematic sampling, gridding the Sampling Frame (Figure 3A), zic-zac design 3 point**s** from starter point to the endpoint (Figure 3B).

Data Sampling

This research has been used simple random sampling (passive sampling) because it is usually fairly representative random samples. In this study, a total of 57 sampling points have been systematically selected. In the first stage, from these points, three fronds have been randomly picked from each part (i.e. high, middle, and low) of the sampling points. On the first day, the fronds are picked from 30 points; on the second day, the fronds are picked from the rest points, which are 27. All symptomatic and asymptomatic leaves were collected from randomly selected fronds before bulked together in a clean polythene bag and brought back directly to the laboratory for analysis.

In the second stage, the samples of parasitoids were collected using hand-picking; and 10 yellow sticker traps have been run at different points on this day. Yellow sticker traps have been tied with a rope to the tree trunk and collected on the next day. The parasitoids were stuck to both parts of the front and back of the yellow sticky traps. Samples collected have been stored in plastic to be transported to the laboratory for the identification process.

Study I: Evaluation of Bagworm Infestation in Oil Palm Plantation

To evaluate the bagworm infestation in an oil palm plantation, this study has been determined the incidence of the oil palm trees accordingly. Quantitative assessment of bagworm infestation incidence has been performed based on bagworm- infestation symptoms. The assessment process has been conducted on selected plants by calculating the percentage of the affected fronds (incidence) for each plant as the following formula:

$$Incidence\ rate = \frac{number\ of\ infected\ branches}{number\ of\ total\ branches} \qquad (1)$$

Infestation incidence has been ranked according to the infestation and severity of bagworm infested leaves. Total branches of each oil palm tree have been observed. In this regard, this research has been observed the infected branches of each selected oil palm tree. Visual observation of the insect symptom on individual plants has been subjected to the severity scale of 0-3 (Table 1 and Figure 4). The incidence of each oil palm tree was rated based on Equation 1.

Table 1. Severity rating used for assessing the severity of the infestation of bagworm symptoms (Aziz et al., 2012).

Damage rating	Level name	Observation
0	No incidence	no observable symptom of the bagworm
1	Low	1-33 % damage of foliate
2	Moderate	34-67 % damage of foliate
3	Severe	68-100 % damage of foliate

Figure 4. The visual appearance of damage rating in the foliar due to bagworm infestation.

Study II: Determination of Bagworm Stages and their Damages

A total number of bagworm was recorded in terms of the dead and alive ones. The dead bagworm was identified based on their movement; if these bagworms don't move, then it considered as dead samples. Bagworm stages have been identified according to their features or size. This process was performed using a formal indicator obtained from the farm manager.

Study III: Evaluation of Parasitoid in Oil Palm Plantation

The parasitoid species identification is done by using Compound Light Microscope and referring to the Handbook of Common Parasitoids and Predators Associated with Bagworms and Nettle Caterpillars in Oil Palm Plantation (MPOB) (Kamarudin et al., 1998). Before the process of identification, the parasitoids which are attached at Yellow Sticker have been immersed in water to isolate parasitoids from the Yellow Sticker. In such a process, forceps are used to pinch parasitoids and put in a petri dish. Then, the petri dish is placed under the Compound Light Microscope for identification.

Data Analysis

In this research, the Statistical Package for the Social Science (SPSS) version 23 has been employed to screen data in terms of coding and checking the collected data are correctly entered. The raw data were entered into a data file in SPSS manually. Firstly, as stated in an earlier study (Zhang et al., 2020), multicollinearity test needs to be performed to indicate that the bagworm stages are highly inter-correlated and small changes in the data values may lead to large changes in the estimates of the coefficients. In this context, bagworm stages are considered independent variables, whilst the incidence rate considered the dependent variable. Variance Inflation Factor (VIF) and tolerance statistics are the two common statistical methods that can be used to assess multicollinearity. It is generally believed that any VIF value that exceeds 10 and tolerance value below than 0.10 indicates a potential problem of multicollinearity (Hair et al., 2006). Other two processes to diagnose the multi-collinearity are: (1) identify all condition indices above the threshold (i.e. 30), and (2) for all condition indices exceeding the threshold, identify variables with variance proportion above 90%. Secondly, the descriptive statistic has been performed for (1) incidence scales to determine which incidence scale is the most spread, (2) the bagworm stages to determine which stage is the most available among others, and (3) the parasitoids species, families and orders to determine the variety of them. Moreover, multiple linear regressions analysis between bagworm stages and incidence rates data has been performed to determine which stage has more impact on the oil palm incidence. Also, in the ArcMap, it has been illustrated the data sets of oil palm incidence and bagworm to include a variety of information and provide the prevalence of them.

RESULTS AND DISCUSSION

Evaluation Result of the Bagworm Infestation in Oil Palm Plantation

The result shows that there are two sampling points with zero incidences, which are 14 and 77; the reason behind that could be their collected branches have been observed with no affected. While coordinate 81 is considered the highest incidence with a value of 93.75%. Table 2 illustrates the data samples picked from 57 oil palm trees. According to equation 1, this table also shows the evaluation result of bagworm infestation in these trees.

Table 2. Data sampling of oil palm trees and evaluation results of bagworm infestation.

Coordinate Tree	No. of branches	No. of infected branches	Incidence rate	Coordinate tree	No. of branches	No. of infected branches	Incidence rate
2	35	5	14.29	40	40	3	7.50
4	34	9	26.47	41	30	7	23.33
5	20	7	35.00	42	40	20	50.00
6	12	1	8.33	43	40	25	62.50
11	20	2	10.00	45	12	2	16.67
12	40	35	87.50	46	10	3	30.00
13	18	3	16.67	47	25	7	28.00
14	1	0	0.00	48	15	10	66.67
15	48	14	29.17	49	20	18	90.00
16	40	3	7.50	50	40	5	12.50
17	32	20	62.50	51	32	17	53.13
19	40	13	32.50	52	40	6	15.00
20	40	22	55.00	53	40	11	27.50
21	40	20	50.00	55	32	5	15.63
22	40	30	75.00	56	40	6	15.00
23	30	16	53.33	58	40	3	7.50
24	40	9	22.50	59	40	9	22.50
25	40	2	5.00	62	40	9	22.50
27	40	2	5.00	63	48	14	29.17
29	48	5	10.42	65	40	4	10.00
31	48	1	2.08	69	40	16	40.00
32	48	15	31.25	70	40	21	52.50
33	42	20	47.62	72	48	20	41.67
34	36	21	58.33	73	42	12	28.57
35	40	19	47.50	77	4	0	0.00
36	23	21	91.30	79	32	23	71.88
37	22	20	90.91	81	32	30	93.75
38	25	20	80.00	100	40	14	35.00
39	20	10	50.00				

Furthermore, the calculated incidences of oil palm trees have been divided into four incidence scales, namely, no incidence, low, moderate, and severe. In this stage, the calculated four severity scales of oil palm trees have been analysed and presented in Table 3.

Table 3. Mean results of incidence scales.

Scales	No incidence	Low	Moderate	Severe
Frequency	2	29	18	8
Percentage	3.5%	50.9%	31.6%	14%

The result of the incidence scales shows that the incidence scales are concerned 50.9% were low incidence, while, 31.6% were moderate incidence. Moreover, around 14% were high incidence, whilst, remaining around 3.5% were no incidence. Then, the mapping results for the incidence rates in the selected area of oil palm plantation are done and distributed. Figure 5 presents the distribution of incidence in the selected oil palm plantation.

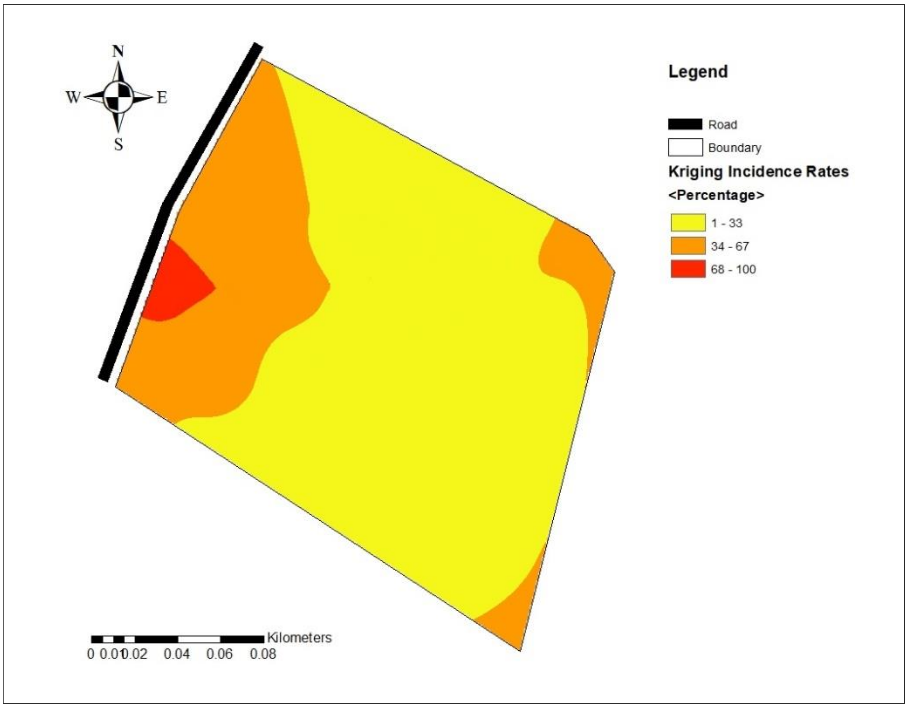

Figure 5. Incidence distribution in the selected oil palm plantation.

The red and orange colours in Figure 5 refer to the high-value distribution, while, the yellow one refers to the low value of incidence rates distribution. The evaluation process of bagworm infestation in oil palm plantation has been performed according to the description above. According to the result, the selected area suffered from a value of 96.5% infestation rate. The low incidence rate was occupied most of the selected area (yellow area in Figure 5); followed by moderate (orange area in Figure 5) and severe (red area in Figure 5), respectively. Severe and moderate incidences are distributed in the west location of the selected oil palm plantation (nearby the main road) as shown in Figure 5. Strong winds, vehicles, animals, and people are considered as factors that have responsible for spreading insects (e.g. bagworms) in the surrounding part (besides the road) that have got entangled with them and thus made high damages in such areas of the plantations (Mahadi & Muhamad, 2012). Vehicles affect the spread of harmful insects including the bagworms in such surrounding part (besides the road) through sticking or carrying them. While the winds can carry and transferred the bagworms effectively because of their lightweight (Halim et al., 2017). Therefore, severe and moderate incidences occurred in those areas compared to the inner side of the plantation. Also, those areas might be contained a lot of bagworm population affecting the incidence. Most of the low incidences were distinguished in the middle of the plantation, that might be contained the lowest bagworm population that impact on the incidence in the oil palm trees.

The Bagworm Stages and Their Damages

In this study found 638 dead out of 5668 total collected bagworms. The dead bagworms have been excluded from further analysis. Thus, seven stages form 5030 live bagworms have been determined (Figure 6). Table 4 illustrates the stages of live bagworms.

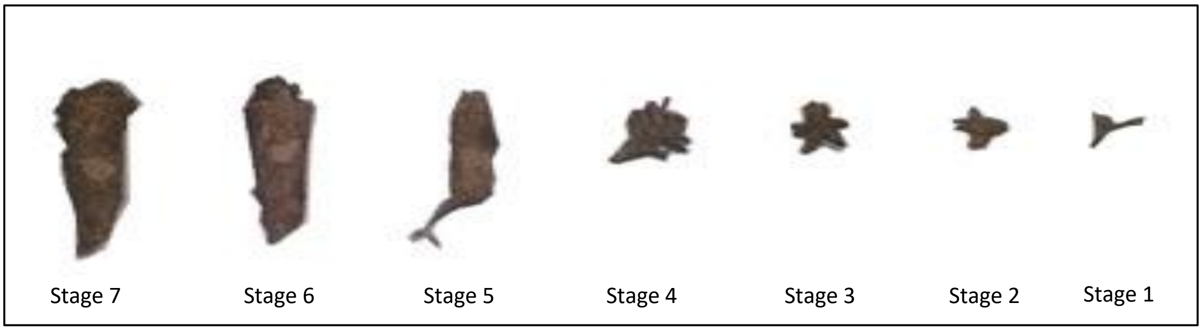

Figure 6. Seven stages of bagworm.

From Table 4, coordinate 36 is considered the highest tree contains bagworms with a total of 363 bagworms. The reason behind that the coordinate 36 was a palm tree contains a large of fronds due to this tree have not been pruned for a long time making it has more than the required fronds number of each palm tree, which is 35-40 fronds for each (Marcelino & Diaz, 2010), making it a suitable environment for bagworms (Samedani et al., 2014).

The highest bagworm stage found in this tree was stage 5 with 180 bagworms, whereas stage 4 with zero bagworms was the lowest one. However, coordinate 14 is considered the lowest tree containing only 2 bagworms in stage 6. This is because coordinate 14 was a palm tree with few fronds, and this is not preferred for bagworms because they are a leaf-feeding pest (Kamarudin & Wahid, 2010). The reason for lacking fronds is that either to excessive pruning of fewer than 32 fronds in the palm or the bagworms eliminated them. Furthermore, to check the multicollinearity amongst the bagworm stages, multicollinearity test is performed and the summary result is presented in Table 5.

This result reveals that the tolerance value ranges of all bagworm stages were from 0.334 to 0.955; that's mean all of these values are above the cut-off 0.10. Moreover, the VIF value for all bagworm stages was below threshold 10, ranged from 1.047 to 2.991. The result also indicated that the condition index value of all bagworm stages was below threshold 30. Nevertheless, there was no variance proportion above 0.9 for these bagworm stages. These results demonstrated that all thresholds were passed and there was no Multicollinearity between S1, S2, S3, S4, S5, S6 and S7. Furthermore, descriptive statistics (i.e. mean and standard deviation) for seven bagworm stages have been done and presented in Table 6.

Table 4. Number of bagworms collected at different stages.

Coordinate Tree	S1	S2	S3	S4	S5	S6	S7	Total	Coordinate tree	S1	S2	S3	S4	S5	S6	S7	Total
2	13	54	8	21	4	5	11	116	40	5	2	0	5	3	6	3	24
4	7	11	2	5	9	0	2	36	41	5	0	2	5	5	9	0	26
5	8	2	7	8	10	11	0	46	42	3	4	5	3	5	33	0	53
6	4	0	6	4	6	2	4	26	43	5	1	21	5	3	13	3	51
11	7	4	6	7	7	17	1	49	45	1	5	26	1	5	3	0	41
12	29	1	11	0	31	47	5	124	46	1	0	236	1	1	11	0	250
13	13	5	2	13	13	2	0	48	47	48	0	216	48	1	2	1	316
14	0	0	0	0	0	2	0	2	48	12	6	22	12	48	0	7	107
15	11	0	4	11	11	14	6	57	49	127	2	8	127	8	4	6	282
16	0	6	1	0	4	3	2	16	50	14	24	3	14	4	1	6	66
17	3	2	5	3	3	0	24	40	51	22	3	5	22	7	5	1	65
19	57	24	0	0	49	0	3	133	52	1	6	5	1	29	0	0	42
20	8	3	8	8	8	3	6	44	53	4	9	3	4	13	0	0	33
21	18	6	4	18	20	4	9	79	55	8	33	5	8	0	6	0	60
22	19	9	7	19	18	5	33	110	56	2	13	1	2	11	2	0	31
23	100	33	29	60	98	1	13	334	58	6	3	1	6	0	24	0	40
24	43	13	13	0	39	2	3	113	59	8	1	48	8	3	1	2	71
25	1	3	0	1	1	11	1	18	62	27	0	12	27	57	11	8	142
27	0	1	11	0	2	2	0	16	63	1	0	127	1	8	11	1	149
29	0	0	0	0	5	0	0	5	65	0	1	14	0	18	2	0	35
31	2	0	3	2	2	4	1	14	69	14	1	22	14	19	0	2	72
32	5	0	57	5	2	1	1	71	70	7	2	1	7	100	4	0	121
33	21	1	8	21	5	5	2	63	72	23	4	1	3	43	1	0	75
34	26	0	18	26	21	0	4	95	73	1	0	1	6	1	5	1	15
35	12	21	19	54	26	0	17	149	77	3	0	2	9	0	0	1	15
36	14	16	100	0	180	6	47	363	79	22	11	4	13	0	0	1	51
37	22	7	43	22	216	12	2	324	81	57	17	17	13	2	6	11	123
38	8	2	1	8	22	24	2	67	100	18	0	47	2	5	2	0	74
39	3	11	0	3	8	3	14	42									

Remark: S1= stage 1, S2= stage 2, S3= stage 3, S4= stage 4, S5=stage 5, S6=stage 6 and S7=stage 7

Table 5. Multicollinearity diagnostics results.

Bagworm stages	Tolerance	VIF	Condition index	Variance Proportion						
				S1	S2	S3	S4	S5	S6	S7
S1	0.334	2.991	1.923	0.04	0.03	0.12	0.05	0.01	0.21	0.00
S2	0.804	1.244	2.038	0.02	0.08	0.11	0.04	0.11	0.03	0.17
S3	0.955	1.047	2.215	0.00	0.04	0.50	0.00	0.03	0.25	0.03
S4	0.354	2.824	2.574	0.01	0.37	0.13	0.01	0.39	0.03	0.00
S5	0.784	1.276	2.987	0.00	0.17	0.01	0.02	0.36	0.03	0.74
S6	0.949	1.054	3.857	0.03	0.22	0.11	0.00	0.00	0.41	0.01
S7	0.763	1.310	5.422	0.89	0.07	0.00	0.87	0.07	0.03	0.03

Remark: S1= stage 1, S2= stage 2, S3= stage 3, S4= stage 4, S5=stage 5, S6=stage 6, S7=stage 7 and VIF= variance inflation factor

Table 6. Mean and standard deviation results of seven bagworm stages.

Bagworm stages	Mean ± Standard Deviation
S1	15.77 ± 5.26
S2	6.72 ± 4.247
S3	21.54 ± 7.696
S4	12.04 ± 6.079
S5	21.39 ± 7.118
S6	6.11 ± 4.68
S7	4.68 ± 2.439

Remark: S1= stage 1, S2= stage 2, S3= stage 3, S4= stage 4, S5=stage 5, S6=stage 6 and S7=stage 7

Stages 3 and 5 are considered the highest stages with the mean values of 21.54% and 21.39, respectively; followed by stages 1, 4, 2, and 6 with the mean values of 15.77%, 12.04,%, 6.72% and 6.11%, respectively. While stage 7 is considered the lowest one with a mean value of 4.68%. The reason behind stage 3 being the highest one amongst other stages is that this stage is considered an early instar bagworm stage and usually, is voracity and more active (Yeoh et al., 2019), in addition to that this stage takes a long time to be transferred to the next stages. The third bagworm instar can be developed into the fourth bagworm instar with the longest period, which is 16-18 days (Firake et al., 2018). However, the seventh bagworm instar is considered as the last stage in the bagworm life cycle. Moreover, mapping and distribution result of the bagworm for each stage in the selected area has been done.

Figure 7 presents the distribution result of seven bagworm stages. In Figure 7, the dark colour refers to the highest distribution value, while the light colour refers to the lowest distribution value. According to the distribution results, there is a clear variation in the distribution of bagworm stages in the selected area. The distribution results provided in maps show that the bagworm population of the first (Figure 7A), third (Figure 7C), fourth (Figure 7D), fifth (Figure 7E), and seventh (Figure 7G) stages more concentrations on the south-western side overlooking the main road or transportation site. It was believed that those stages were transmitted through transportation from other infected sites. This is because this part overlooks the transportation site (Megı´as, 2014). While the second (Figure 7B) stage scattered on the south side of the selected oil palm plantation, and sixth (Figure 7F) stages scattered on the south and north-east sides of the selected oil palm plantation; this is because that those areas might be beside other infected sites, which could invade the neighbouring fields immediately (Carrasco et al., 2010). After that, to determine which bagworm stage has more impacting on the incidence rate of the oil palm plantation, linear regression analysis test need to be performed. Linear regression is a linear approach to modelling the relationship between incidence rates of oil palm trees and one or more bagworm stages. The case of one independent variable is called simple linear regression. As in this research has seven bagworm stages (independent variables), thus, multiple linear regressions need to be performed to determine which stage has more impact on the oil palm incidence as follows. Practically, the coefficient illustrates the impact of each bagworm stage on the oil palm trees incidence as presented in Table 7.

Table 7. Coefficient result of the bagworm stages and oil palm trees incidence.

Bagworm stages		**Incidence**
S1	Beta	0.364
	Significant	0.034
S2	Beta	-0.191
	Significant	0.082
S3	Beta	-0.033
	Significant	0.739
S4	Beta	0.053
	Significant	0.746
S5	Beta	0.236
	Significant	0.035
S6	Beta	0.263
	Significant	0.011
S7	Beta	0.406
	Significant	0.001

Remark: S1= stage 1, S2= stage 2, S3= stage 3, S4= stage 4, S5=stage 5, S6=stage 6 and S7=stage 7

The significant values results are 0.034, 0.082, 0.739, 0.746, 0.035, 0.011, and 0.001 for the seven stages, respectively. Amongst other stages, 1, 5, 6, and 7 are considered the highest positive significant stages that impact on the incidence rates of oil palm trees due to their significant values are less than 0.05. Moreover, stage 7 is the most impacted stage on the oil palm trees incidence with a Beta value of 0.406. While stage 1 is the second-highest impacted stage on the oil palm trees incidence with a Beta value of 0.364; followed by stages 6 and 5 with the Beta values of 0.263 and 0.236, respectively.

According to the experiment, the incidence rates of oil palm trees are impacted by two life bagworm stages, namely, small bagworm caterpillars (i.e. stage 1) and larger bagworm caterpillars (i.e. stages 5, 6 and 7). The reason behind that leaves may be damaged by having the outer layer of cells (epidermis) removed by small bagworm caterpillars or all tissues but major leaf veins removed by larger bagworm caterpillars (Firake et al., 2018). Higher bagworm stages have been more caused the incidence in the oil palm trees compared with lower stages; high potential for leading toward the plant death. In sum, the multi regression statistical test has been permitted to this study confidently determine which bagworm stage has a higher influence on the incidence of oil palm trees. Significant differences of those impacted bagworm stages (1, 4, 5, 6 and 7) mean that those stages have a positive relationship with the incidence rates and thus those stages have been damaged the oil palm trees.

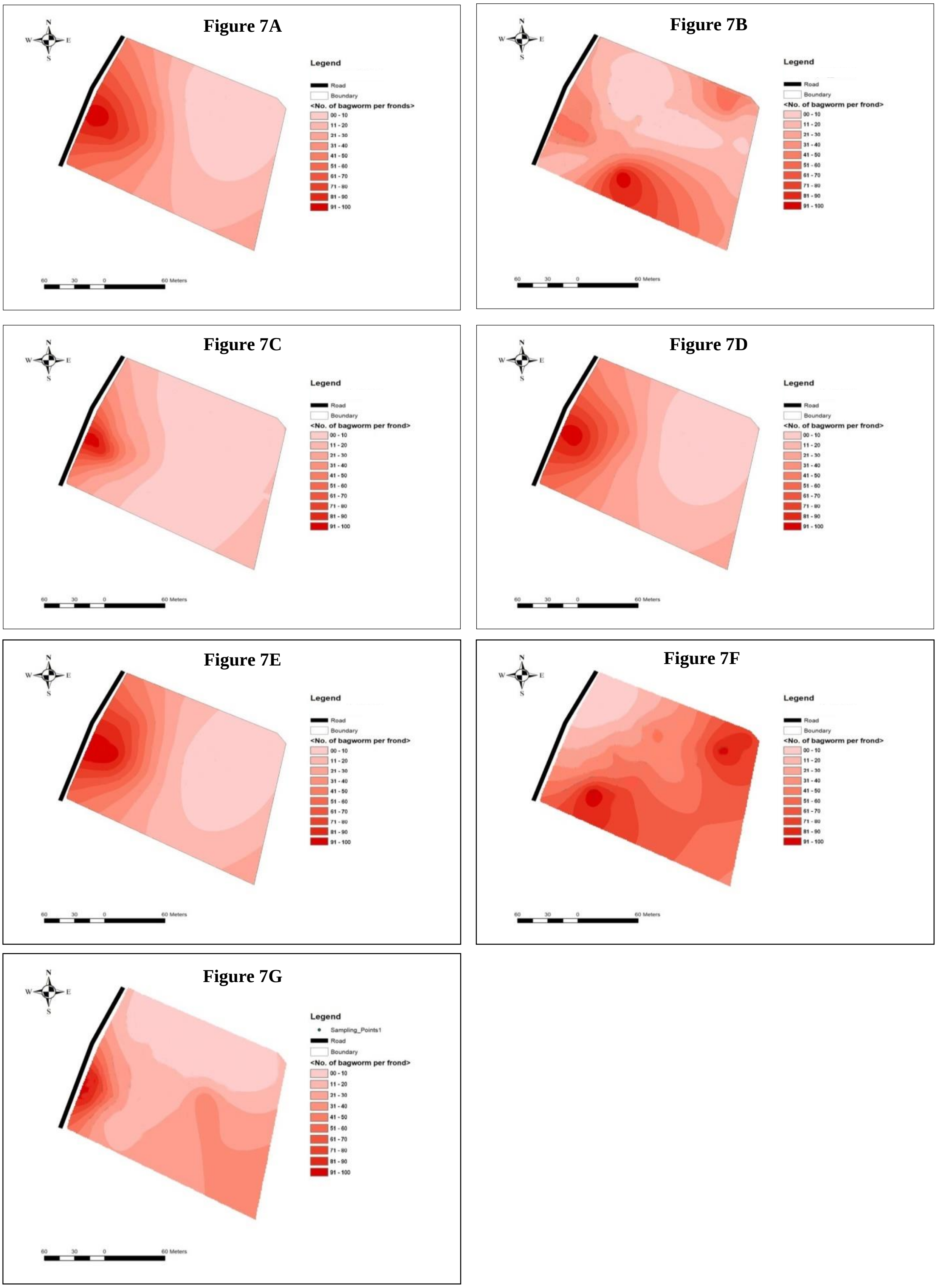

Figure 7. Distribution of bagworm stages in the selected oil palm plantation, First stage (Figure 7A), Second stage (Figure 7B), Third stage (Figure 7C), Fourth stage (Figure 7D), Fifth stage (Figure 7E), Sixth stage (Figure 7F) and Seventh stage (Figure 7G).

Evaluation Result of Parasitoids in Oil Palm Plantation

The parasitoid has been screened and identified in the laboratory after collecting the samples from the oil palm plantation. Table 8 illustrates the number of individuals of parasitoids collected in the first and second sampling.

Table 8. Number of parasitoid species, families and order collected from first and second samplings.

First Sampling			
Species	Family	Order	Total
Aphanogmus thylax	Caraphronidae	Hymenoptera	3
Elasmus sp.	Elasmidae	Hymenoptera	2
Pediobius anomalus	Eulophidae	Hymenoptera	5
Pediobius elasmi	Eulophidae	Hymenoptera	1
Pediobius imbrues	Eulophidae	Hymenoptera	1
Sympiesis sp.	Eulophidae	Hymenoptera	2
Tetrastichus planipennisi	Eulophidae	Hymenoptera	7
Brachymeria cerinata	Chalcididae	Hymenoptera	1
Goryphus bunoh	Ichneumonidae	Hymenoptera	3
Paraphylax varius	Ichneumonidae	Hymenoptera	1
Spinaria spinator	Ichneumonidae	Hymenoptera	7
Total Individuals			33
Second Sampling			
Species	Family	Order	Total
Aphanogmus thylax	Caraphronidae	Hymenoptera	2
Eupelmus catoxanthae	Eupelmidae	Hymenoptera	1
Pediobius anomalus	Eulophidae	Hymenoptera	2
Sympiesis sp.	Eulophidae	Hymenoptera	3
Tetrastichus planipennisi	Eulophidae	Hymenoptera	3
Brachymeria cerinata	Chalcididae	Hymenoptera	1
Apanteles aluella	Braconidae	Hymenoptera	1
Goryphus bunoh	Ichneumonidae	Hymenoptera	1
Paraphylax varius	Ichneumonidae	Hymenoptera	5
Spinaria spinator	Ichneumonidae	Hymenoptera	2
Total Individuals			20

In the first sampling, a total of 11 types of parasitoid species associated with *Metisa plana* have been found in the oil palm plantation. These types are belonging to five families, namely, Caraphronidae, Elasmidae, Eulophidae, Chalcididae, and Ichneumonidae. While in the second sampling, a total of 10 types of parasitoid species associated with *Metisa plana* have been found, which belong to six families, namely, Caraphronidae, Eupelmidae, Eulophidae, Chalcididae, Braconidae, Ichneumonidae. As in the first sampling, all families are represented by only one order, which is a Hymenoptera.

Table 9. Parasitoid species found during the determination process of the bagworm stages.

Species	**Family**	**Order**	**Total**
Tetrastichus planipennisi.	Eulophidae	Hymenoptera	7
Goryphus bunoh	Ichneumonidae	Hymenoptera	1
Paraphylax varius	Ichneumonidae	Hymenoptera	1
Spinaria spinator	Ichneumonidae	Hymenoptera	1
Total Individuals			10

As shown in Table 9, a total of 10 types of parasitoid species associated with *Metisa plana* have been founded during the determination process of the bagworm stages. These types are belonging to two families, namely, Eulophidae, and Ichneumonidae. As in the first and second samplings, all families are represented by only one order, which is a Hymenoptera. Moreover, Table 10 illustrates a total of the data collection of the parasitoid species.

Table 10. Total of the parasitoid species, families and order.

Species	Family	Order	Total
Aphanogmus thylax	Caraphronidae	Hymenoptera	5
Elasmus sp.	Elasmidae	Hymenoptera	2
Eupelmus catoxanthae	Eupelmidae	Hymenoptera	1
Pediobius anomalus	Eulophidae	Hymenoptera	7
Pediobius elasmi	Eulophidae	Hymenoptera	1
Pediobius imbrues	Eulophidae	Hymenoptera	1
Sympiesis sp.	Eulophidae	Hymenoptera	5
Tetrastichus planipennisi	Eulophidae	Hymenoptera	17
Brachymeria cerinata	Chalcididae	Hymenoptera	2
Apanteles aluella	Braconidae	Hymenoptera	1
Goryphus bunoh	Ichneumonidae	Hymenoptera	5
Paraphylax varius	Ichneumonidae	Hymenoptera	7
Spinaria spinator	Ichneumonidae	Hymenoptera	9
Total Individuals			63

According to the experiment, no other insect order presents as much biological diversity as Hymenoptera. Hymenoptera is considered as parasitoids (Lindauer, 2019) that can be used in the biological control of bagworms in the oil palm plantation due to the following reasons. Firstly, Hymenopterans are herbaceous or predacious or live as parasitoids within or on other insects and they have value in the control of harmful insects in agroecosystems (Ayasse & Paxton, 2001). Secondly, the structural characteristics, sensory capabilities, and behavioural repertoire of the female wasp of Hymenoptera combine to enable her to locate and successfully oviposit on bagworm hosts. The Hymenoptera females are capable of drilling through tens of centimetres of wood with their ovipositor to find and parasitize the hidden beetle larva. Thirdly, Hyperparasitism the parasitic habit of one species upon another parasitic species as also attracted attention. Polyembryony, the development of many individuals (as many as 1,000) from a single egg, is an unusual phenomenon occurring in some members of the families Chalcididae and Proctotrupidae. Parthenogenesis (production of young by females that are not fertilized by males) also occurs in some form (Lindauer, 2019). In sum, Hymenoptera order is considered a parasitoid that could be impacting on the bagworms populations in the oil palm plantation (Mahadi & Muhamad, 2012). The results of data analysis of collected Parasitoid have been provided. Table 11 presents the percentage of the appearance of each species and family in the collected data.

Table 11 shows that the highest family is Eulophidae with a percentage value of 49.206%. While Eupelmidae and Braconidae are considered the lowest families with a percentage value of 1.587% for each. Moreover, this research has been determined the percentage of the appearance for each species under each related family. As presented in Table 11, for each mentioned species, the percentage of the appearance for each species under each related family is 100%. While Eulophidae and Ichneumonidae families have contained different species. Table 12 presents the percentage of the appearance for each species under Eulophidae and Ichneumonidae families.

Table 11. Percentage of the appearance of each species and family.

Species	
Species	**%**
Aphanogmus thylax	7.937
Elasmus sp.	3.175
Eupelmus catoxanthae	1.587
Pediobius anomalus	11.111
Pediobius elasmi	1.587
Pediobius imbrues	1.587
Sympiesis sp.	7.937
Tetrastichus planipennisi	26.984
Brachymeria cerinata	3.175
Apanteles aluella	1.587
Goryphus bunoh	7.937
Paraphylax varius	11.111
Spinaria spinator	14.286
Family	
Caraphronidae	7.937
Elasmidae	3.175
Eupelmidae	1.587
Eulophidae	49.206
Chalcididae	3.175
Braconidae	1.587
Ichneumonidae	33.333

Table 12. Percentage of the Appearance for Each Species under Eulophidae and Ichneumonidae Families

Eulophidae Family	
Species	%
Pediobius anomalus	22.581
Pediobius elasmi	3.226
Pediobius imbreus	3.226
Sympiesis sp.	16.129
Tetrastichus planipennisi	54.839
Ichneumonidae Family	
Species	%
Goryphus bunoh	23.810
Paraphylax varius	33.333
Spinaria spinator	42.857

Table 12 reveals that the *Tetrastichus planipennisi* is the highest species under Eulophidae family with a percentage value of 54.839%. While the species *Pediobius elasmi* and *Pediobius imbrues* have been considered the lowest species with a percentage value of 3.226% for each. Table 12 reveals that the *Spinaria spinator* is the highest species under Ichneumonidae family with a percentage value of 42.857%; followed by *Paraphylax varius* and Goryphus with the percentage values 33.333% and 23.810%, respectively. In sum, the Eulophidae family is considered the highest family parasitoid in this study, which has been used in the parasitism on the pests of the oil palm *Elaeis guineensis* Jacq, the gregarious Eulophidae: *Tetrastichus planipennisi* is considered as the highest parasitoid species observed by this study, which emerge from the late instars up to the pupal stages of bagworm *Metisa plana* (Rizali et al., 2019). This is what was observed during the separation of bagworms into seven stags. In line with the experiment performed, many studies have been stated that Tetrastichus parasitoid species can be efficiently used to parasitism the bagworm in the oil palm plantations (Norman & Othman, 2016).

CONCLUSION

The selected oil palm plantation in Perak suffered from various infestation rates including low (i.e. 50.9%), moderate (i.e. 31.6%), high (i.e. 14%), and no incidence (i.e. 3.5%). The incidence rates of oil palm trees were impacted by two life bagworm stages, namely, small bagworm caterpillars (i.e. stage 1) and larger bagworm caterpillars (i.e. stages 5, 6 and 7). Finally, in the evaluation of parasitoid, no other insect order presented as much biological diversity as Hymenoptera. As a future direction, the parasitism between the identified parasitoid and bagworm will be investigated and evaluated.

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