Journal of Oil Palm Research Vol. 29 (1) March 2017 p. 55 – 65

EFFICACY OF PHEROMONE TRAPPING AND AERIAL SPRAYING OF *Bacillus thuringiensis* (Bt) FOR CONTROLLING BAGWORM, *Metisa plana* WALKER (Lepidoptera: Psychidae) IN YONG PENG, JOHOR, MALAYSIA

MOHD NAJIB AHMAD*; NORMAN KAMARUDIN*; SITI NURULHIDAYAH AHMAD*; OTHMAN ARSHAD*; MOHAMED MAZMIRA MOHD MASRI*; RAMLE MOSLIM* and A KUSHAIRI*

ABSTRACT

Recurring bagworm outbreak is a major problem in the oil palm plantation. The continuous use of chemical insecticides to control bagworm outbreaks, the lack of beneficial plants in the plantation to attract natural enemies, and infestation in neighbouring plantations were reported as the contributing factors for bagworm outbreaks. Hence, the aim of this study is to evaluate the efficacy of pheromone trapping application for controlling bagworm, Metisa plana *in Mukim Chaah smallholdings in Yong Peng, Johor, Malaysia. The installation of pheromone traps at Mukim Chaah smallholdings was carried out at four different locations for two consecutive generations of* M. plana. *Results showed that the first and second generations of pheromone trapping at Kg Sg Berlian and Kg Sawah Padi, without the aerial spraying of* Bacillus thuringiensis *(Bt) have successfully reduced 89% and 77% of bagworm population, respectively. Meanwhile, another trapping session conducted at Kg Temehel and Kg Seri Sepakat, together with the aerial spraying of Bt, resulted in the first and second generations of pheromone trapping to successfully reduced 94% and 85% of bagworm population, respectively. Together with the aerial spraying of Bt, the two consecutive generations of pheromone trapping application at two different areas in Mukim Chaah smallholdings successfully reduced bagworm population to manageable levels.*

Keywords: efficacy, pheromone trapping, receptive females.

Date received: 21 April 2016; **Sent for revision:** 27 April 2016; **Received in final form:** 14 September 2016; **Acepted:** 6 October 2016.

INTRODUCTION

In Malaysia, the major insect pests capable for causing outbreaks in oil palm plantation are bagworms and nettle caterpillars. The economic impact has been a moderate bagworm attack of 10%-50% leaf damage may cause 43% yield loss (Wood *et al*., 1972; Basri and Kevan, 1995). Without proper control measures, the population of bagworms will increase to above its threshold level, thereby causing serious outbreak. The bagworm is a leaf-eating caterpillar concealed within its carrot-shaped bag, which is constructed from bits of leaflet upon which it feeds (Barlow, 1982). The large numbers of bagworm attack can defoliate the entire palm canopy subsequently resulting in yield loss. The defoliation of palm canopies would result in 30% reduction of the yield over the next two years (Wood *et al*., 1972).

As part of an Integrated Pest Management (IPM) programme, pheromone trapping is a simple method for controlling bagworms. Mass trapping

* Malaysian Palm Oil Board, 6 Persiaran Institusi, 43000 Kajang, Selangor, Malaysia.
E-mail: norman@mpob.gov.my

has been used either in long-term pest management such as codling moth (*Cydia pomonella*), pink bollworm (*Pectinophora gossypiella*) and fruit flies, or in the eradication of invasive species [*e.g.* gypsy moth (*Lymantria dispar*) and boll weevil (*Anthonomus grandis grandis*)] (El-Sayed *et al*., 2006). The strategy to control the bagworm population is by mass trapping the male adults, subsequently limiting their chances to mate with the females for propagating the next generation (Norman *et al*., 2010; 2011).

Since November 2011, bagworm outbreaks were found and reported in Mukim Chaah smallholdings in districts of Batu Pahat and Labis, Johor, Malaysia, covering 3300 ha. The severity of the infestation was increasing with the total infested area reported in October 2013 at approximately 8916 ha (Mazmira *et al*., 2015). Thus, the pheromone trapping method for controlling bagworm outbreaks was carried out at two different locations for controlling *Metisa plana* in 2013.

MATERIALS AND METHODS

Installation of Traps

Pheromone mass trapping was carried out for two consecutive generations of *M. plana* at four different areas, starting from 13 – 20 May 2013 (first generation) and 23 – 26 July 2013 (second generation) at Kg Sg Berlian and Kg Sawah Padi, and on 24 – 27 September 2013 (first generation) and 27 - 30 November 2013 (second generation) at Kg Temehel and Kg Sri Sepakat in Mukim Chaah smallholdings, Yong Peng, Johor, Malaysia (*Figure 1*). The determination of each generation was calculated according to *M. plana* life cycle, which was reported by Basri and Kevan (1995). The amount of traps used during the first and second generations of pheromone trapping conducted at Kg Sg Berlian and Kg Sawah Padi in Mukim Chaah smallholdings were 500 and 550 units, respectively. The different number of trap fixed in first and second generations was due to increase of infested areas. Then, the pheromone trapping session was moved to new infested areas, Kg Temehel and Kg Sri Sepakat for two consecutive generations of trapping. The amount of traps used during the first and second generations of pheromone trapping conducted at Kg Temehel and Kg Sri Sepakat in Mukim Chaah smallholdings were 410 and 400 units, respectively. The number of trap was reduced in the second generation due to some areas have recovered, as an effect from the first generation trapping.

The installation of traps commenced at the onset of emergence of male adults in May 2013. Females or pupal samples were evaluated based on the emergence of adults and receptive female (Mohd Rizuan *et al*., 2011). The female pupa is always larger than the male (Norman *et al*., 2011). Receptivity of the female was determined by the opening of the anterior end of the pupae bag plus the intermittent protrusion of the female's head and thorax from this opening (Basri and Kevan, 1995; Norman and Othman, 2006). Female will stay receptive for about nine days and closed the anterior end of the pupae bag after this period.

A pheromone trap was made by inserting and stretching a white colour plastic bag, 20 x 30 inches in between two 2-m long wooden poles. Each plastic was evenly sprayed with polybutene glue (Chemi Bond, Malaysia). Each trap was baited with four receptive bagworm females, with two females at each hole on the plastic (*Figure 2*). Fifteen traps were placed in three transects (five traps per transect) along the non-harvesting paths within a hectare of the bagworm-infested plot. The distance between each trap was about 20 m (Norman *et al*., 2011).

Aerial Spray Operation

The aerial spray of *Bacillus thuringiensis*, MPOB Bt1 product, Ecobac-1 (EC) for controlling second

Note: 1 - Kg Sri Sepakat, 2 - Kg Sg Berlian, 3 - Kg Sawah Padi and 4 - Kg Temehel.

Figure 1. GPS map showing location of two consecutive generations of pheromone trapping conducted at two different areas in Mukim Chaah smallholdings, Yong Peng, Johor, Malaysia.

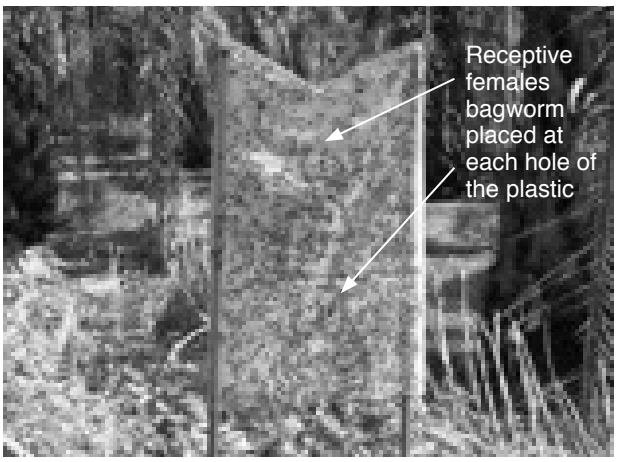

Figure 2. Pheromone trap installed using receptive females of bagworm.

generation of *M. plana* population was conducted at Kg Sg Berlian, Kg Sawah Padi, Kg Temehel and Kg Sri Sepakat in Mukim Chaah smallholdings, Yong Peng, Johor, Malaysia between 28 October – 8 November 2013. The total infested area treated with Ecobac-1 (EC) was 8916 ha. During treatment preparation, 40 litres of Ecobac-1 (EC) was mixed with 1000 litres of water in the aircraft's tank. The aircraft model, AgCat was used during aerial spray operation under IPM programme.

Bagworm Census after Trapping

Trapping activity took three to seven days to be completed for each session. Therefore, the larval population in the trapped area was censused to determine the density of the bagworm, number of trapping rounds required and the number of traps to be installed in the next trapping application.

Data Analysis

Data on mortality was analysed using one-way analysis of variance (ANOVA) run on SPSS software version 11.5. When ANOVA result achieved was significant, the means were separated by the Least Significant Difference (LSD) test at $P < 0.05$ using the same software. The histogram was plotted with standard error using SigmaPlot version 11.0.

RESULTS AND DISCUSSION

Pheromone Trapping Session at Kg Sg Berlian

From *Table 1*, the first generation of trapping captured 388.8 moths per trap (MPT) or 18.5 MPT per day at 21 days after trap (DAT). In the second generation of trapping session, results showed that the average male moths caught were 82.5 MPT or 3.9 MPT per day, which was 79% less compared to the first trapping session. The two consecutive generations of pheromone trapping session had reduced the subsequent total population of live bagworm as in *Figure 3*. Prior to the first trapping session (*Table 2*), the mean live larvae population recorded was 3.7 larvae per frond (LPF) at stages 6 and 7, and the total live bagworm population recorded was 52.9 total bagworms per frond. However, after six weeks of trapping, the increment of mean live larvae numbers was observed from 3.7 LPF (before trapping) to 104.5 LPF (after trapping), with 96% increment. This scenario could be attributed to successful mating of the females and the existing of stages 6 (1.2 LPF) and 7 (2.5 LPF) larvae (*Table 2*) which were observed before the trapping started.

Subsequently, the next generation (second generation) of live bagworm population decreased for two months after the first trapping session, with the mean of 18.7 bagworms per frond (BPF) recorded on 23 July 2013 (before second generation of trapping). The decrease of live bagworm could be attributed by weather conditions (Hasber *et al*., 2012). The second generation of trapping session resulted in moderate reduction of total live bagworm numbers, 69%. The average live larvae and total bagworm observed before trapping session was 1.3 LPF and 18.7 total BPF, respectively. Again, stages 6 and 7 larvae population was observed with the average of 0.2 LPF and 1.0 LPF, respectively. Nevertheless, at 6 weeks after trapping (WAT), the number of total bagworm decreased to 5.4 total BPF and the mean live larvae increased to 5.4 LPF (*Table 2*). The increase of larvae population was likely due to the existence of stages 6 and 7 larvae before trapping which resulted in the formation of live

TABLE 1. EFFECT OF RECEPTIVE *M. plana* FEMALES IN ATTRACTING MALE MOTHS AFTER TWO CONSECUTIVE PHEROMONE TRAPPING SESSIONS AT KG SG BERLIAN, MUKIM CHAAH SMALLHOLDINGS

Generations/dates of recording	Male moths trapped at 21 DAT		
	Range	Mean/trap	Mean/trap/day
1 (3 June 2013)	0-3 352	388.8±26.8a	18.5±1.3a
2 (14 August 2013)	0-857	82.5±6.2b	3.9±0.3b

Note: Different letters in row indicate significant difference at P<0.05 after Least Significant Difference (LSD) test. Data was recorded at 21 days after trapping (DAT).

females and successful mating, contributing to emergence of larvae in the next generation, as indicated in *Table 2*. This result may also be attributed to incorrect timing of receptive females collected and used during second generation of the trapping session. Norman and Othman (2006) reported that the effective female receptivity period was about nine days. After that, the effect of attracting male moths will decrease drastically.

In conclusions, the two consecutive pheromone trapping sessions conducted at Kg Sg Berlian from May to July 2013 were able to reduce mean live bagworm population from 52.9 BPF at 0 WAT (13 May 2013) of the first generation to 5.8 BPF at 6 WAT (3 September 2013) of the second generation, with high reduction of the bagworm population observed, 89% (*Table 2*).

Pheromone Trapping Session at Kg Sawah Padi

From *Table 3*, the first generation of trapping captured 165.6 MPT or 7.9 MPT per day at 21 DAT. In the second generation of trapping session, result showed that the mean male moths caught were 26.3 MPT or 1.3 MPT per day, which was 84% less compared to the first trapping session. The two consecutive generations of pheromone trapping session had reduced the subsequent population of total live bagworm as in *Figure 3*. Prior to the first trapping session (*Table 4*), the mean live larvae population recorded was 0.4 LPF at stage 7, and the total live bagworm population recorded was 23.2 total. However, after six weeks of trapping, the increment of mean live larvae numbers was observed from 0.4 LPF (before trapping) to 37.3 LPF (after trapping), with 99% increment. This scenario could be attributed to successful mating of the females and the existing stage 7 (0.4 LPF) larvae (*Table 4*) which were observed before the trapping started.

Subsequently, the next generation (second generation) of live bagworm population decreased two months after the first trapping session, with the mean of 12.1 BPF. The decrease of live bagworm could be attributed to weather conditions (Hasber *et al*., 2012). The second generation of trapping session resulted in the reduction of total live bagworm numbers, 55%. The mean live larvae and total bagworm observed before trapping session was 0.8 LPF and 12.1 total BPF, respectively. Again, stages 6 and 7 larvae population was observed with the mean of 0.2 LPF and 0.6 LPF, respectively (*Table 4*). Nevertheless, at 6 WAT, the number of total bagworm decreased to 5.4 total BPF and the mean live larvae increased to 5.4 LPF (*Table 4*). The increase of larvae population was likely due to the existence of stages 6 and 7 larvae before trapping which resulted in the formation of live females and successful mating, contributing to high emergence of larvae in the next generation, as indicated in *Table 4*. This result may also be attributed to incorrect timing of receptive females collected and used during second generation of the trapping session. Norman and Othman (2006) reported that the effective female receptivity period was about nine days. After that, the effect of attracting male moths will decrease drastically.

In conclusions, the two consecutive pheromone trapping sessions conducted at Kg Sawah Padi from May to July 2013 was able to reduce the mean live bagworm population from 23.2 BPF at 0 WAT (13 May 2013) of the first generation to below threshold level, 5.4 BPF at 6 WAT (3 September 2013) of the second generation, with 77% reduction of the bagworm population (*Figure 4* and *Table 4*).

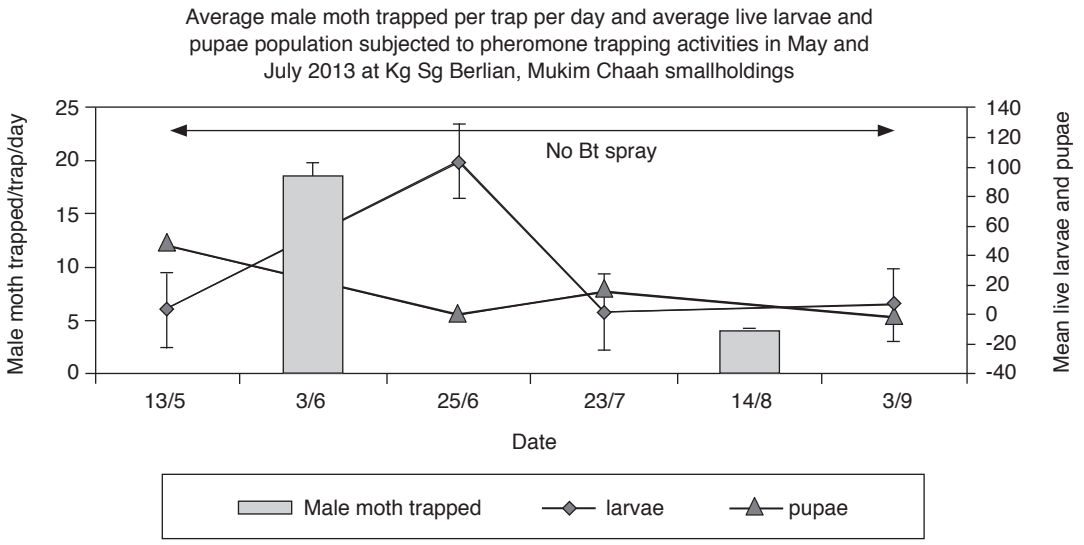

Figure 3. Changes in the population density of average live larvae and pupae after two consecutive pheromone trapping sessions, May 2013 – July 2013 at Kg Sg Berlian, Mukim Chaah smallholdings.

TABLE 2. DYNAMIC OF BAGWORM POPULATION OBSERVED IN THE FIRST AND SECOND GENERATIONS OF PHEROMONE TRAPPING SESSION AT KG SG BERLIAN, MUKIM CHAAH SMALLHOLDINGS

Generation/ palm No., n	Time of census	Total larvae, LPF		Pupae, PPF		Total bagworm (larvae + pupae), BPF	
		Range	Mean/stage	Range	Mean	Range	Mean
First / n = 60	Before trapping (13 May 2013)	0-14	1.2±0.2 – L6 2.5±0.3 – L7 **3.7±0.4**	1-129	49.1±4.2	1-130	52.9±4.1
	After trapping (25 June 2013)	0-361	0.1±0.1 – L2 31.6±3.5 – L3 49.8±4.6 – L4 22.6±3.6 – L5 1.8±0.9 – L6 **104.5±10.8**	0-0	0	0-361	104.5±10.8
Second / n = 60	Before trapping (23 July 2013)	0-5	0.2±0.1– L6 1.0±0.1 – L7 **1.3±0.1**	0-37	17.4±1.1	0-42	18.7±1.2
	After trapping (3 September 2013)	0-23	1.2±0.2 – L2 3.8±0.4 – L3 0.8±0.1 – L4 **5.8±0.7**	0-0	0	0-23	5.8±0.7

Note: LPF - larvae per frond. PPF - pupae per frond. BPF - bagworms per frond.

TABLE 3. EFFECT OF RECEPTIVE *M. plana* FEMALES IN ATTRACTING MALE MOTHS AFTER TWO CONSECUTIVE PHEROMONE TRAPPING SESSIONS AT KG SAWAH PADI, MUKIM CHAAH SMALLHOLDINGS

Generations/dates of recording	Male moths trapped at 21 DAT		
	Range	Mean/trap	Mean/trap/day
1 (3 June 2013)	0-1 460	165.6±43.3a	7.9±2.1a
2 (14 August 2013)	0-102	26.3±9.9b	1.3±0.5b

Note: Different letters in row indicate significant difference at P<0.05 after Least Significant Difference (LSD) test. Data was recorded at 21 days after trapping (DAT).

Pheromone Trapping Session at Kg Temehel

In September 2013, the trapping session was carried out at a new infested area, Kg Temehel, located 35 km from the previous trapping location. For the first generation of trapping session, the mean male moths caught was 307.7 MPT or 14.7 MPT per day. For the second generation, the number of male moths caught per trap was 51.5 MPT or 2.5 MPT per day. The number of moths caught in the second generation was found to decrease significantly (P<0.05), 83% as compared to the first generation male moths trapped (*Table 5*).

In the first generation of trapping session, result showed that the total live bagworm numbers reduced significantly, 48%, one month after trapping session (*Figure 5* and *Table 6*). The total bagworm observed before trapping session was 64.5 total BPF and at 6 WAT, the number decreased to 33.5 total BPF (*Table 6*). Although the stages 6 (0.3 LPF) and 7 (1.7 LPF) larvae were observed before the trapping session, the declining trend could be attributed to the correct timing of receptive females collected (Norman and Othman, 2006) during the trap fixing session. The trapping session for the first generation was conducted during early morning, at 7 am. According to Mohd Rizuan *et al.* (2011), the receptive female (unfertilised / virgin stage), female with yellowish eggs (fresh eggs of gravid female) and female with brownish eggs (matured eggs of gravid female) mated twice at period between 7.45 – 8.21 am.

Subsequently, the next generation (second generation) of live bagworm population decreased

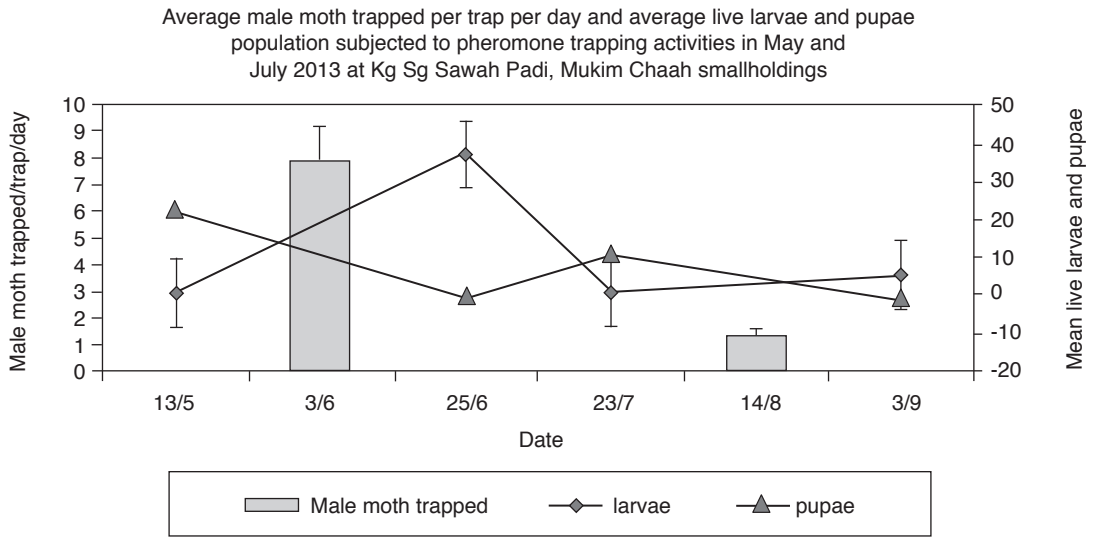

Figure 4. Changes in the population density of average live larvae and pupae after two consecutive pheromone trapping sessions, May 2013 – July 2013 at Kg Sawah Padi, Mukim Chaah smallholdings, Johor, Malaysia.

TABLE 4. DYNAMIC OF BAGWORM POPULATION OBSERVED IN THE FIRST AND SECOND GENERATIONS OF PHEROMONE TRAPPING SESSION AT KG SAWAH PADI, MUKIM CHAAH SMALLHOLDINGS

Generation/ palm No., n	Time of census	Total larvae, LPF		Pupae, PPF		Total bagworm (larvae + pupae), BPF	
		Range	Mean/stage	Range	Mean	Range	Mean
First/ n = 10	Before trapping (13 May 2013)	0-1	0.4±0.2 – L7 **0.4±0.2**	4-52	22.8±5.2	4-52	23.2±5.3
	After trapping (25 June 2013)	0-108	0.1±0.1 – L2 12.7±5.2 – L3 21.5±8.9 – L4 3.0±3.1 – L5 **37.3±14.8**	0-0	0	0-108	37.3±14.8
Second/ n = 10	Before trapping (23 July 2013)	0-3	0.2±0.1– L6 0.6±0.2 – L7 **0.8±0.3**	0-21	11.3±2.5	0-24	12.1±2.7
	After trapping (3 September 2013)	0-17	1.3±0.8 – L2 4.0±1.2 – L3 0.1±0.1 – L4 **5.4±2.0**	0-0	0	0-17	5.4±2.0

Note: LPF - larvae per frond. PPF - pupae per frond. BPF - bagworms per frond.

TABLE 5. EFFECT OF RECEPTIVE *M. plana* FEMALES IN ATTRACTING MALE MOTHS AFTER TWO CONSECUTIVE PHEROMONE TRAPPING SESSIONS AT KG SAWAH PADI, MUKIM CHAAH SMALLHOLDINGS

Generations/dates of recording	Male moths trapped at 21 DAT		
	Range	Mean/trap	Mean/trap/day
1 (17 October 2013)	0-1 896	307.7±23.8a	14.7±1.1a
2 (17 December 2013)	0-1 110	51.3±22.3b	2.5±1.1b

Note: Different letters indicate significant difference at P<0.05 after Least Significant Difference (LSD) test. Data was recorded at 21 days after trapping (DAT).

from 33.5 BPF on 6 November 2013 (after first trapping) to 21.5 BPF on 27 November 2013 (before second trapping) (*Table 6*), with 36% reduction of bagworm population. The decrease of live bagworm could be attributed to weather conditions (Hasber *et al*. 2012) and the effect of aerial spraying of Bt product on 28 October 2013 (*Figure 5*). The second generation of trapping session resulted in a high reduction of total live bagworm numbers, 81% from 27 November 2013 to 7 January 2014 (*Table 6*). The mean live larvae and total bagworm observed before trapping session was 0.5 LPF and 21.5 total BPF, respectively. Again, stages 6 and 7 larvae population was observed with the average of 0.1 LPF and 0.5 LPF, respectively. Nevertheless, at 6 WAT, the number of total bagworm decreased

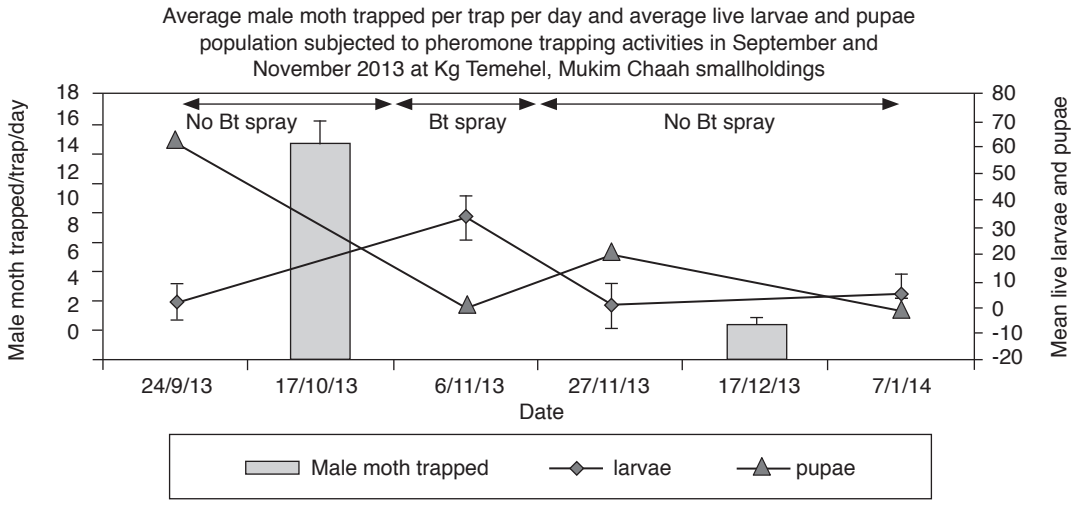

Figure 5. Changes in the population density of average live larvae and pupae after two consecutive pheromone trapping sessions, September 2013 - November 2013 at Kg Temehel.

TABLE 6. DYNAMIC OF BAGWORM POPULATION OBSERVED IN THE FIRST AND SECOND GENERATIONS OF PHEROMONE TRAPPING SESSION AT KG TEMEHEL, MUKIM CHAAH SMALLHOLDINGS, JOHOR, MALAYSIA

Generation /palm No., n	Time of census	Total larvae, LPF		Pupae, PPF		Total bagworm (larvae + pupae), BPF	
		Range	Mean/stage	Range	Mean	Range	Mean
First / n = 70	Before trapping (24 September 2013)	0-6	0.3±0.1 – L6 1.7±0.1 – L7 **2.1±0.2**	10-212	62.4±5.3	10-213	64.5±5.4
	After trapping (6 November 2013)	0-341	0.6±0.1 – L2 12.6±2.6 – L3 16.0±5.0 – L4 4.2±1.9 – L5 **33.5±8.8**	0-0	0	0-341	33.5±8.8
Second / n = 30	Before trapping (27 November 2013)	0-3	0.1±0– L6 0.5±0.1 – L7 **0.5±0.1**	0-85	20.9±3.1	0-88	21.5±3.1
	After trapping (7 January 2014)	0-14	0.1±0 – L2 0.2±0.1 – L3 26.1±0.5 – L4 1.2±0.3 – L5 0.1±0.1 – L6 **4.1±0.8**	0-0	0	0-14	4.1±0.8

Note: LPF - larvae per frond.
PPF - pupae per frond.
BPF - bagworms per frond.

to 4.1 total BPF and the mean live larvae increased to 4.1 LPF (*Table 6*). The increase of larvae population was likely due to the existence of stages 6 and 7 larvae population, 0.5 LPF (mean) before trapping which contributed to low emergence of larvae in the next generation, as indicated in *Table 6*. This result may be attributed to correct timing of receptive females collected and used during second generation of the trapping session. The high reduction observed during second generation of trapping might due to precise timing of trapping. As a result, at 6 WAT, the mean live larvae recorded was only 4.1 LPF as compared to the first generation of pheromone trapping session, 33.5 LPF at 6 WAT (*Table 6*).

The two consecutive pheromone trapping sessions conducted at Kg Temehel from September to November 2013 was able to reduce mean live bagworm population from 64.5 BPF at 0 WAT (24 September 2013) of the first generation to 4.1 BPF at 6 WAT (7 January 2014) of the second generation, with 94% reduction of the bagworm population (*Table 6*).

Pheromone Trapping Session at Kg Seri Sepakat

In September 2013, another trapping session was carried out at a new infested area, Kg Sri Sepakat. For the first generation of trapping session, the mean male moths caught was 114.7 MPT or 5.5 MPT per day. For the second generation, the number of male moths caught per trap was 36.0 MPT or 1.7 MPT per day. The number of moths caught in the second generation was found to decrease significantly ($P<0.05$), 69% as compared to the first generation male moths trapped (*Table 7*).

In the first generation of trapping session, result showed that the total live bagworm numbers reduced significantly, 73%, one month after trapping session (*Figure 6* and *Table 8*). The total bagworm observed before trapping session was 23.3 total BPF and at 6 WAT, the number decreased to 6.3 BPF (*Table 8*). Although the stages 6 (0.1 LPF) and 7 (1.0 LPF) larvae were observed before the trapping session, the declining trend could be attributed to the correct timing of receptive females collected (Norman and Othman, 2006) during the trap fixing session.

TABLE 7. EFFECT OF RECEPTIVE *M. plana* FEMALES IN ATTRACTING MALE MOTHS AFTER TWO CONSECUTIVE PHEROMONE TRAPPING SESSIONS AT KG SRI SEPAKAT, MUKIM CHAAH SMALLHOLDINGS

Generations/month	Male moths trapped		
	Range	Mean/trap	Mean/trap/day
1 (24-27 September 2013)	0-1 008	114.7±32.1a	5.5±1.5a
2 (27-30 November 2013)	0-270	36.0±15.2b	1.7±0.7b

Note: Different letters indicate significant difference at $P<0.05$ after Least Significant Difference (LSD) test. Data was recorded at 21 days after trapping (DAT).

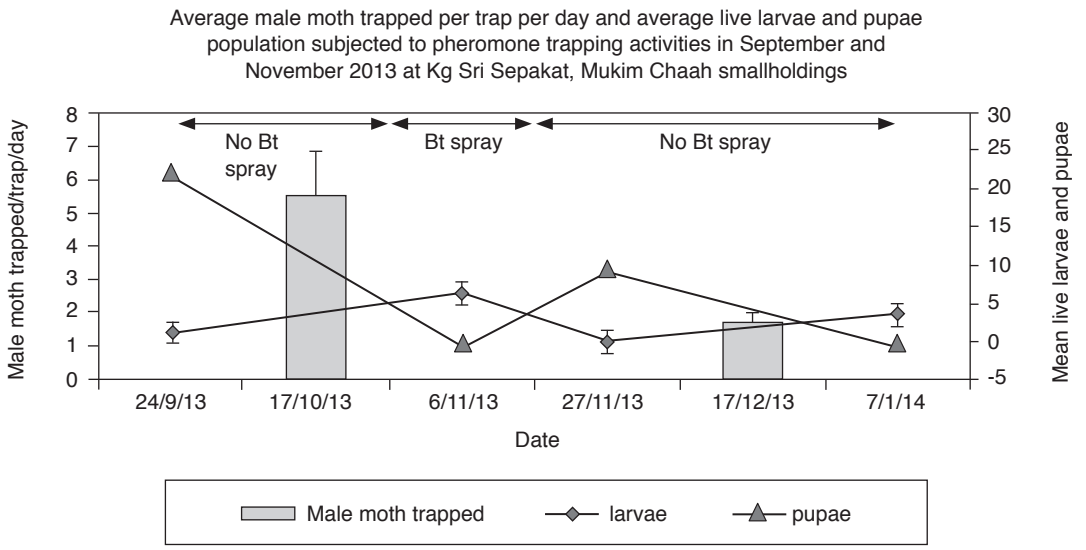

Figure 6. Changes in the population density of average live larvae and pupae after two consecutive pheromone trapping sessions, September 2013 – November 2013 at Kg Sri Sepakat.

Subsequently, the next generation (second generation) of live bagworm population increased from 6.3 BPF on 6 November 2013 (after first trapping) to 9.6 BPF on 27 November 2013 (before second trapping) (*Table 8*). The increase of live bagworm could be attributed to the male moths which escaped the trapping had successful mating in the previous trapping session (first generation of trapping – 24 September 2013) and ballooning process from neighbouring area (Hasber *et al*., 2012). The second generation of trapping session resulted in a reduction of total live bagworm numbers, 64% from 27 November 2013 to 7 January 2014 (*Table 8*). The mean live larvae and total bagworm observed before trapping session was 0 LPF and 9.6 total BPF, respectively. In the second generation of trapping, no live larvae were recorded before trapping started. Subsequently, at 6 WAT, the number of total bagworm decreased to 3.5 BPF and the mean live larvae increased to 3.5 LPF (*Table 8*). The increase of larvae population was likely due to the male moths which escaped the trapping had successful mating, as indicated in *Table 8*. However, the total bagworm population was reduced by 64% in the second generation of trapping and this result may be attributed to correct timing of receptive females collected and used during second generation of the trapping session. The reduction observed during second generation of trapping might due to precise timing of trapping. As a result, at 6 WAT, the mean live larvae recorded was only 3.5 LPF as compared to previous trapping session. 6.3 LPF (*Table 8*).

The two consecutive pheromone trapping sessions conducted at Kg Sri Sepakat from September to November 2013 were able to reduce the mean live bagworm population from 23.3 BPF at 0 WAT (24 September 2013) of the first generation to below threshold level, 3.5 BPF at 6 WAT (7 January 2014) of the second generation, with 85% reduction of the bagworm population (*Table 8*).

As a comparison, the fixing of pheromone traps without involving Bt spray at Kg Sg Berlian and Kg Sawah Padi could reduce 89% and 77% of the bagworm population, respectively, from the first generation (May 2013) to the second generation (July 2013) of pheromone trapping sessions (*Table 9*). Meanwhile, the pheromone trapping sessions involving Bt spray at Kg Temehel and Kg Sri Sepakat resulted in 94% and 85% reduction of the bagworm population from the first generation (September 2013) to the second generation (November 2013) of pheromone trapping sessions (*Table 9*). The decline at four different areas could be attributed to the correct timing of receptive females collected (Norman and Othman, 2006) during the trap fixing session and minimal number of late larvae existed prior to the start of the trapping session (*Tables 2, 4, 6* and *8*). On 28 October 2013, the aerial spraying operation using Bt product was carried out at Kg Temehel and Kg Seri Sepakat (*Table 9*). Subsequently, the average bagworm reduction at both places was slightly higher, 89.5% as compared to Kg Sg Berlian and Kg Sawah Padi, with 83% reduction and without involving Bt spray. Furthermore, the mean

TABLE 8. DYNAMIC OF BAGWORM POPULATION IN THE FIRST AND SECOND GENERATIONS OF PHEROMONE TRAPPING SESSION AT KG SRI SEPAKAT, MUKIM CHAAH SMALLHOLDINGS

Generation /palm No., n	Time of census	Total larvae, LPF		Pupae, PPF		Total bagworm (larvae + pupae), BPF	
		Range	Mean/stage	Range	Mean	Range	Mean
First / n = 10	Before trapping (24 September 2013)	0-3	0.1±0.1 - L6 1.0±0.3 - L7 **1.1±0.3**	8-43	22.2±3.6	9-44	23.3±3.7
	After trapping (6 November 2013)	0-14	0.1±0.1 - L2 5.1±1.3 - L3 1.1±0.4 - L4 **6.3±1.5**	0-0	0	0-14	6.3±1.5
Second / n = 10	Before trapping (27 November 2013)	0-0	**0**	0-28	9.6±3.1	0-28	9.6±3.1
	After trapping (7 January 2014)	0-12	0.3±0.2 - L3 1.9±0.6 - L4 1.3±0.6 - L5 **3.5±1.3**	0-0	0	0-12	3.5±1.3

Note: PPF - pupae per frond. BPF - bagworms per frond.

TABLE 9. BAGWORM REDUCTION AFTER TWO CONSECUTIVE PHEROMONE TRAPPING SESSIONS AT FOUR DIFFERENT AREAS

Trapping area	Date of trapping	Percent reduction of bagworms, % (two consecutive generations of *M. plana*)	Remarks
Kg Sg Berlian	May and July 2013	89	Not involved Bt spray
Kg Sawah Padi		77	
Kg Temehel	September and November 2013	94	Involved Bt spray
Kg Seri Sepakat		85	

live larvae population observed was decreased to 33.5 LPF and 6.3 LPF at Kg Temehel and Kg Sri Sepakat, respectively, on 6 November 2013 due to aerial spray effect.

CONCLUSION

Pheromone trapping application at four different areas in Mukim Chaah smallholdings has successfully reduced the bagworm population to a manageable level. The correct timing of pheromone trapping based on the receptivity of the live bagworm females ensured the effectiveness of pheromone trapping. The correct stage of bagworm prior to the start of the pheromone trapping session is important to bring down the bagworm population in subsequent generation. Mass trapping of the male bagworm moths can complement IPM for bagworms by reducing the bagworm population in subsequent generations.

ACKNOWLEDGEMENT

The authors would like to thank the Director-General of MPOB for permission to publish this article. Special thanks to TUNAS South Zone 1 for their technical and logistic support and Mukim Chaah smallholders for allowing MPOB to fix the pheromone traps in their areas. Last but not least to the staff of Entomology and Ecological Research laboratory, MPOB who involved in initiating and conducting the pheromone trapping activity.

REFERENCES

BARLOW, H S (1982). *An Introduction to the Moths of South East Asia*. Art Printing Works Sdn Bhd, Kuala Lumpur. 305 pp. Chapter 2 - PSU Knowledge Bank kb.psu.ac.th/psukb/bitstream/2010/5855/1/313724.pdf

BASRI, M W and KEVAN, P G (1995). Life history and feeding behaviour of the oil palm bagworm, *Metisa plana* Walker (Lepidoptera: Psychidae). *Elaeis, 7(1)*: 18-35. MPOB, Bangi. portal.mpob.gov.my/html/01_r&d/01_b01_05a_03.html

EL-SAYED, A M; SUCKLING, D M; WEARING, C H and BYERS, J A (2006). Potential of mass trapping for long-term pest management and eradication of invasive species. *J. Economic Entomology, 99(5)*: 1550-64. www.ars.usda.gov/research/publications/Publications.htm?seq_no_115=...

HASBER, S and NOOR HISHAM, H (2012). Evaluation of several chemical control approaches against bagworm, *Metisa plana* Walker (Lepidoptera: Psychidae) in FELDA oil palm plantations. *The Planter, 88 (1040)*: 785-799. Evaluation of Several Chemical Control Approaches against Bagworm ...www.researchgate.net/publication/236019714_Evaluation_of_Several...

MAZMIRA, M M M; NAJIB, M A; NORHAZWANI, K; NORMAN, K and SITI RAMLAH, A A (2015). Implementing an Integrated Pest Management (IPM) program for bagworm control in oil palm smallholdings in Johor. *Proc. of the PIPOC 2015 International Palm Oil Congress - Oil Palm: Powering the World, Sustaining the Future*. p. 15-20. www.researchgate.net/publication/368708846_IMPLEMENTING_AN_INTEGRATED _PEST..

MOHD RIZUAN, Z A; NOOR HISHAM, H; SUKRI, T I and ABU HASSAN, A (2011). Field evaluation of mating behavior of male moth towards receptive female of the bagworm, *Metisa plana* (Lepidoptera: Psychidae). *Proc. of the PIPOC 2011 International Palm Oil Congress: Palm Oil – Fortifying and Energizing the World*. p. 71-74. www.researchgate.net/publication/256605694_FIELD_EVALUATION_OF...

NORMAN, K and OTHMAN, A (2006). Potential of using the pheromone trap for monitoring and controlling the bagworm, *Metisa plana* Wlk (Lepidoptera: Psychidae) in a smallholder plantation. *J. Asia Pasific Entomology, 9(3)*: 281-285. Pheromone mass trapping of bagworm moths,

Metisa plana Walker ... www.sciencedirect.com/science/article/pii/S1226861509001058

NORMAN, K; SITI NURULHIDAYAH, A; OTHMAN, A and BASRI, M W (2010). Pheromone mass trapping of bagworm moths, *Metisa plana* Walker (Lepidoptera:Psychidae), for its control in mature oil palms in Perak, Malaysia. *J. Asia Pasific Entomology, 13(2)*: 101-106. DOI:10.1016/j.aspen.2009.11.003.

NORMAN, K; SITI NURULHIDAYAH, A and OTHMAN, A (2011). A sticky vane trap for mass trapping of the bagworm, *Metisa plana* in oil palm. *MPOB Information Series No. 487*. *A Sticky Vane trap for Mass trapping Metisa plana in oil palm* palmoilis. mpob.gov.my/publications/TOT/TT-487.pdf

WOOD, B J; CORLEY, R H V and GOH, K H (1972). Studies on the effect of pest damage on oil palm yield. *Advances in Oil Palm Cultivation*. Incorporated Society of Planters. p. 360-379. Pest Control in Malaysia's Perennial Crops: A Half Century Perspective ... link.springer.com/article/10.1023/B:IPMR.0000027501.91697.49