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Efficacy of Insecticide and Bioinsecticide Ground Sprays to Control *Metisa plana* Walker (Lepidoptera: Psychidae) in Oil Palm Plantations, Malaysia

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Abstrak: Keberkesanan racun serangga sintetik trichlorfon, lambda-cyhalothrin, cypermethrin *emulsion concentrated* (EC) dan cypermethrin *emulsion water based* (EW) serta racun serangga biologi, *Bacillus thuringiensis* subsp. *kurstaki (Btk)*, telah dinilai pada 3, 7, 14 dan 30 hari selepas rawatan (DAT) bagi mengawal larva *Metisa plana* pada kelapa sawit (*Elaeis guineensis*) di Malaysia. Walaupun semua rawatan racun serangga sintetik berkesan mengurangkan populasi larva *M. plana*, trichlorfon, lambda-cyhalothrin dan cypermethrin EC adalah yang paling cepat bertindak. Populasi larva jatuh di bawah paras ambang ekonomi (ETL) 30 hari selepas satu pusingan rawatan bagi racun serangga sintetik. Penggunaan *Btk*, bagaimanapun, memberi keputusan yang kurang berkesan dengan populasi larva berada di atas ETL selepas rawatan. Dari segi produktiviti, semburan paras tanah menggunakan alatan *power sprayer* kurang produktif dan mempunyai luas litupan yang rendah. Teknik semburan paras tanah menggunakan peralatan power sprayer mungkin tidak sesuai untuk mengawal serangan *M. plana* di kawasan yang luas. Menggunakan teknik aplikasi ini seorang pekerja hanya mampu menyiapkan semburan sebanyak 2–3 hektar sehari. Oleh itu, teknik semburan paras tanah adalah disyorkan mengawal serangan perosak di kawasan yang kecil dari 50 hektar.

Kata kunci: *Metisa plana*, Kelapa Sawit, Bioinsektisid, Racun Serangga Sintetik, Malaysia

Abstract: The effectiveness of the synthetic insecticides trichlorfon, lambda-cyhalothrin, cypermethrin emulsion concentrated (EC) and cypermethrin emulsion water based (EW) and a bio-insecticide, *Bacillus thuringiensis* subsp. *kurstaki* (*Btk*), was evaluated at 3, 7, 14 and 30 days after treatment (DAT) for the control of *Metisa plana* larvae in an oil palm (*Elaeis guineensis*) plantation in Malaysia. Although all synthetic insecticides effectively reduced the larval population of *M. plana*, trichlorfon, lambda-cyhalothrin and cypermethrin EC were the fastest-acting. The larval population dropped below the economic threshold level (ETL) 30 days after a single application of the synthetic insecticides. Application of *Btk*, however, gave poor results, with the larval population remaining above the ETL post treatment. In terms of operational productivity, ground spraying using power spray equipment was time-consuming and resulted in poor coverage. Power spraying may not be appropriate for controlling *M. plana* infestations in large fields. Using a power sprayer, one man could cover 2–3 ha per day. Hence, power spraying is recommended during outbreaks of infestation in areas smaller than 50 ha.

Keywords: *Metisa plana*, Oil Palm, Bioinsecticides, Synthetic Insecticides, Malaysia

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INTRODUCTION

Malaysia is the world's largest producer and exporter of palm oil, accounting for 52.0% of world production and 61.1% of world exports (Carter *et al.* 2007). The rapid development of oil plantations in Malaysia has coincided with the emergence of various pests that threaten oil palm (*Elaeis guineensis*) production in this country and cause substantial losses in the annual oil palm crop production (Yap 2005; Tan *et al.* 2008; Kok *et al.* 2012).

The bagworm family (Lepidoptera: Psychidae) includes approximately 1000 described species and 300 genera distributed worldwide (for reviews, see Rhainds 2000 and Rhainds & Sadof 2009). *Metisa plana* Walker bagworms are sessile caterpillars that feed on oil palm leaves and use leaf pieces to cover their silken cases (Rhainds *et al.* 2002; Rhainds *et al.* 2008; Rhainds *et al.* 2009; Kamarudin *et al.* 2010). Typically, the bagworm larvae prefer the upper surface of the leaf for eating and the lower surface for resting and development (Basri *et al.* 1994; Basri & Kevan 1995).

M. plana is an important pest of oil palm in Southeast Asia (Wood 1971; Basri *et al.* 1994; Basri & Kevan 1995; Rhainds *et al.* 2002; Rhainds *et al.* 2008, Kamarudin *et al.* 2010; Kok *et al.* 2012), and it is well-known for its destructive effect on oil palm in Malaysia (Basri 1993; Kamarudin *et al.* 1994; Tan *et al.* 2008) and Indonesia (Sudarsono *et al.* 2011). The bagworm can cause up to 50% defoliation of oil palm trees, resulting in severe yield loss of up to 10 tons of fresh fruit bunch (FFB) per acre (Wood *et al.* 1973). During the last decade, several studies have indicated that *M. plana* is the most serious and ubiquitous pest of oil palms in Malaysia (Norman & Basri 2007).

Several methods have been suggested for controlling *M. plana* in oil palm plantations (Rhainds 2000; Koul & Dhaliwal 2002;Tan *et al.* 2008; Rhainds *et al.* 2009, Sudarsono *et al.* 2011; Kok *et al.* 2012). During population outbreaks, chemical control is the fastest and most effective method of suppressing and maintaining *M. plana* populations below the action threshold (Yap 2000). Application of pesticides from the ground using a knapsack sprayer is the most common way to control indicated bagworm populations, especially in young oil palm trees (Basri *et al.* 1988; Sudarsono *et al.* 2011). The organophosphate insecticides trichlorfon and chlorpyrifos and the phyrethroid insecticides cypermethrin and lambda-cyhalothrin are commonly applied as soil drenches (Basri *et al.* 1988; Chung 1998; Yap 2005). Rhainds *et al.* (2009) found that chlorantraniliprole and indoxacarb also provided effective control of bagworm populations. In their study, chlorantraniliprole had a 10-day residual effect and thus may be effective for protecting oil palms against bagworms over a sustained period. Similarly, Kok *et al.* (2012) found that trichlorfon (1900.0 ppm), chlorantraniliprole (50.0 ppm) and cypermethrin (75.0 ppm) provided effective control of bagworms under laboratory conditions and might prove useful for *M. plana* management.

In addition, biological control using natural enemies (pathogens, parasitoids and predators) has been highlighted in modern bagworm management as an environmentally safe strategy (Basri *et al.* 1996; Ramlah *et al.* 2003; Cheong *et al.* 2010). Numerous biocontrol agents such as *Cotesia*

(=*Apanteles*) *metesae* (Sankaran & Syed 1972), *Cosmelestes picticeps* (Hemiptera: Reduviidae) and *Dolichogenidea metasae* (Hymenoptera: Braconidae) (Cheong *et al.* 2010) were applied to control the bagworms. Although entomopathogenic fungi including *Paecilomyces fumosoroseus* and *Metarhizium anisopliae* have been shown to provide bagworm control under laboratory conditions, results under field conditions have not been reliable (Cheong *et al.* 2010). Numerous experiments have demonstrated that various subspecies of the bacterial pathogen *Bacillus thuringiensis* (*Bt*) have been shown to provide good control of lepidopteran pests and can provide effective control of insect pests (Koul & Dhaliwal 2002) including *M. plana* (Tan *et al.* 2008). However, results of field studies using *Bt* for bagworm control have been ambiguous (Ramlah *et al.* 2003; Tan *et al.* 2008). Despite previous experiments, the efficacy of *Bt* subsp. *kurstaki* (*Btk*) applications for the control of *M. plana* in Malaysia is still not well enough established to permit its recommendation as the primary control technique in oil palm estates (Basri *et al.* 1994; Basri *et al.* 1996; Tan *et al.* 2008; Cheong *et al.* 2010; Kok *et al.* 2012). Experiments assessing the efficacy of field applications of *Bt* for control of *M. plana* in Malaysia are urgently needed. Currently, information is lacking on the field efficacy of many biological and chemical insecticides, and primitive techniques for their application hinder the development of effective programs for managing bagworms in Malaysia (Felda Agricultural Services Sdn. Bhd. [FASSB] 2005).

Therefore, the present study was conducted to determine the efficacy of synthetic insecticides and a bio-insecticide (*Btk*) applied as ground sprays for controlling *M. plana* populations in young oil palm fields. Furthermore, the operation cost and the efficacy of the ground sprays using power sprayer equipment was assessed.

MATERIALS AND METHODS

Insecticides and Bioinsecticide Field Assessments

All field assessments were carried out in a young oil palm plantation (5 years old) located in Federal Land Development Authority (FELDA) Besout 06, Sungkai, Perak, Malaysia to determine the efficacies of the synthetic insecticides trichlorfon, lambda-cyhalothrin, cypermethrin emulsion concentrated (EC) and cypermethrin emulsion water based (EW) (Halex Sdn. Bhd., Johor Bahru, Malaysia) as well as the bioinsecticide *Btk* for the control of *M. plana* populations. The *Btk* was obtained from Abbott Laboratories, Chicago. The experimental design was a randomised complete block design (RCBD) with four blocks (replicates). Each block consisted of 6 plots (each plot containing 8 rows of 7 plants) with a total of 336 young palm trees (21 × 16) in a block. Two rows of palm plants were maintained as a buffer zone between plots. Treatments, dosages of active ingredient (a.i.) and dosages of insecticides and bioinsecticide used are shown in Table 1. The control plot was treated only with water. Four replicates were used for each treatment.

Table 1: Application of insecticides used in the field trial.

Treatment code	Active ingredient	Dosage/application*
T1	*Btk* 17,600 IU/mg	0.260%
T2	Trichlorfon 95 SP%	0.095%
T3	Lambda-cyhalothrin EC 2.8%	0.003%
T4	Cypermethrin EC 5%	0.018%
T5	Cypermethrin EW 10%	0.009%
T6	Control (water)	Nil

Notes: SP = soluble powder; *dosage recommended by manufacturer

Insecticides were applied using a two-nozzle power sprayer with pressure of 35 kg/cm^2. The time spent for the operations at each plot was recorded to determine the spraying efficiency and productivity. The power sprayer required a high volume of water to ensure a thorough coverage of the palm trees. The volume of water was standardised at 5 L per tree. Prior to application, the sprayer was calibrated to ensure satisfactory insecticide coverage of each treated palm.

Bagworms were counted prior to the application of insecticide. Three palms were selected randomly in each plot. The middle frond of the selected palms was cut, and the number of larvae of *M. plana* on the sampled leaves was counted and recorded. Insecticide was then applied, and post-census counts of the *M. plana* populations were conducted 3, 7, 14 and 30 days after treatments (DAT). The damage in the canopy was assessed visually as a percentage.

Data Analysis

Percentages of *M. plana* larval mortality in the treated plots were corrected with the percent mortality at control plot with Schneider-Orelli's equation (Püntener 1981) as follows:

CM% = (percentage of mortality in C) – (percentage of mortality in T) / (100% of mortality in C)

where CM = corrected mortality, T = treated plots and C = control plots.

To compare the insecticides' efficacy as well as the time of treatment used in controlling the bagworms, two-way ANOVA followed by multiple comparison tests (Tukey's tests) were considered significant at $p<0.05$ (Statistical Package for the Social Sciences [SPSS Inc., Chicago] version 13) using the actual numbers of larval mortality. The operational productivity and cost for all treatments in this study were calculated to evaluate the cost-effectiveness of the control process.

RESULTS AND DISCUSSION

Evaluation of the Synthetic Insecticides and Bioinsecticides

During population monitoring of bagworms at 3, 7, 14 and 30 DAT, we found that the average number of bagworm larvae per frond was significantly lower in all the treatment plots compared to the control plots. All synthetic insecticides were more effective in controlling *M. plana* than *Btk*. The two-way ANOVA results (Table 2) showed a significant difference in the mean number of *M. plana* of each treatment by the day of treatment (F = 5.152, p<0.05). The results of Tukey's tests showed that all insecticides caused a significant reduction in the number of bagworms after treatment compared to the control plot. At 3 DAT, population of *M. plana* decline by an average of 80.00% in all the insecticide-treated plots and by 61.15% in *Btk*-treated plots. The lambda-cyhalothrin was the most effective insecticide, as the bagworm population dropped by 92.18%, followed by trichlorfon (87.35%), cypermethrin EW (81.70%) and cypermethrin EC (76.63%).

At 3 DAT, the average number of bagworm larvae in trichlorfon- and lambda-cyhalothrin-treated plots was significantly different compared to the control plot (F = 4.79, p<0.05). Similarly, the larval population in all insecticide-treated plots declined after 7 DAT compared to the control plot. As expected, the average number of larvae was the highest in *Btk*-treated plots, indicating the lowest efficacy (68.70%). After 7 DAT, the larval population in lambda-cyhalothrin-, trichlorfon- and cypermethrin 10% EW-treated plots was reduced by 95.98%, 95.91% and 95.40%, respectively. However, cypermethrin 5.5% EC had the lowest effectiveness among the applied insecticides, as the larval population dropped only by 92.92%. At 14 DAT, the larval population of bagworms dropped significantly by >98% in all insecticide-treated plots and was reduced by 83.76% in *Btk*-treated plots (F = 9.94, p<0.05).

Thirty days after the treatment, the population of bagworm larvae was remarkably low (reduction was >99%) in all insecticide-treated plots in comparison with the control plot (F = 49.74, p<0.05). At that time, the larval population of bagworm fell below the economic threshold level (ETL) (5 larvae/frond) in the plots treated with synthetic insecticide. The average number of larvae in *Btk*-treated plots was 23.1 larvae/frond indicating efficacy of 97.19%. This was significantly lower than the number in untreated control plots, but still higher than the economic threshold.

Although only water was applied to the control plots, considerable mortality was reported, which was perhaps due to biotic and abiotic factors. The biotic interactions as well as environmental conditions have been shown to play important roles in regulating the larval community and suppressing the bagworm population (Basri 1993; Ho 2002). Under natural field conditions, the intraspecific competition of *M. plana* for the niche as well as the food source is evident, especially during population peaks (Rhainds 2000).

Table 2: Means±SE and results of two-way ANOVA of *M. plana* larvae number before and after the treatments with different insecticides. The percentage of reduction in the larval population in relation to control plots is shown in parenthesis.

Treatment	Pre-census	3 DAT	7 DAT	14 DAT	30 DAT
Btk	821.3±10.3[a]	319.1±14.7[ab] (61.15)	257.1±14.9[ac] (68.70)	133.4±12.8[a] (83.76)	23.1±2.7[a] (97.19)
Triclorfon 95% SP	803.6±23.5[a]	101.6±2.3[b] (87.35)	36.9±2.1[b] (95.40)	8.6±1.6[b] (98.92)	1.2±1.1[bc] (99.85)
Lambda-cyhalothrin 2.8% EC	1226.1±14.3[a]	95.8±3.2[b] (92.18)	49.3±1.7[ab] (95.98)	11.6±1.4[b] (99.05)	2.8±0.3[b] (99.77)
Cypermethrin 5.5% EC	1197.2±18.5[a]	279.8±4.3[ab] (76.63)	84.8±5.1[ab] (92.92)	19.5±1.1[ab] (98.37)	0.3±0.1[c] (99.97)
Cypermethrin 10% EW	1209.4±19.1[a]	221.3±8.7[ab] (81.70)	49.4±1.3[ab] (95.91)	17.4±2.5[ab] (98.56)	3.5±0.3[b] (99.71)
Control	903.1±17.78	654.9±10.8[ab] (27.48)	562.2±10.8[c] (37.75)	448.1±7.9[c] (50.37)	83.6±3.1[d] (90.74)
ANOVA F-value	1.23	4.79	7.43	9.94	49.74
p-value	0.35	0.12	0.02	0.01	0.00

Note: Similar letters are not significantly different based on Tukey multiple comparison test ($p>0.05$).

Despite the percentage of reduction in the population of *M. plana* in the plot treated with *Btk* being high (97.19%) at 30 DAT, the population was reduced too late to prevent the severe damage of the palm leaves caused by the activity of bagworms for a long period (1 month). Our findings showed that palm trees in the *Btk*-treated and control plots suffered 70% canopy damage compared with only 5% in the insecticides-treated plots. According to *Program Pemantauan Perosak Tanaman* (PPPT 2006), untreated oil palm plots may experience from 50% to 70% canopy damage (resulting in 70% yield loss) during 2 consecutive years of bagworm infestation. Consequently, it was suggested that failure to reduce the bagworm population below the ETL after 30 DAT of infestation might cause continuous outbreaks.

In the present study, we found the ground spraying of all insecticides was an effective application technique to control this pest in the field in single round of treatment, especially after 30 DAT. All synthetic insecticides including trichlorfon, cypermethrin and lambda-cyhalothrin were effective against bagworm through ground spraying, as they reduced bagworm populations below the ETL at 30 DAT (<5 larvae/frond). This was in agreement with the findings of Chung (1998), who reported that trichlorfon and cypermethrin efficiently reduced bagworm populations below the ETL at 30 DAT in an oil palm plantation in Selongor, Malaysia. Similarly, Syed and Salleh (1991) demonstrated that application of trichlorfon at the rate of 1 kg (95%) per hectare was very effective to control *M. plana* larvae in a single treatment. Furthermore, Kok *et al.* (2012) found that trichlorfon (1900 ppm), chlorantraniliprole (at 50 ppm) and cypermethrin (at 75 ppm) was the fastest-acting insecticides on *M. plana* larvae under laboratory conditions.

However, single treatment using *Btk* did satisfactorily control *M. plana* larvae compared to the synthetic insecticides. Application of *Btk* was not efficient to reduce the larval population below ETL, suggesting that *Btk* is not an effective control method for high-density infestations of *M. plana* (>50 larvae/ frond). Otherwise, regular application of *Btk* is required to reduce the population below ETL. Under laboratory conditions, Tan *et al.* (2008) found high larval mortalities (70%–100%) when treated with *Btk* at concentrations from 20 to 100 ppm after 7 DAT. In contrast, Kok *et al.* (2012) found that *Btk* at 324 ppm was the slowest-acting insecticide to control *M. plana* larvae under laboratory conditions. Thus, the results obtained from laboratory and field assessments may show conflicting results due to variability in the application conditions and the ambient environment. Further studies are urgently needed to optimise the application conditions of *Bt* for effective control of bagworm larvae in oil palm plantations.

Operational Productivity and Cost

The productivity of the ground spraying technique was estimated based on the time consumed per application, which was an average of 6.92 h (4.50 h/ha) (Table 3). A field team of 3 workers sprayed approximately 2 hectares per man-day. Arundi (1971) suggested that the productivity of ground spraying could be increased to 8 hectares per team-day at the spray volume of 280 L if a mist-blower (Conomist®) is used. This air-blast mist blower has been reported to cover 15 to 20 hectares per day at a spray volume of 150 to 250 L per hectare depending on ground conditions, palm height and canopy thickness (Chung 1998).

Cypermethrin EC appeared to be the cheapest chemical insecticide, followed by lambda-cyhalothrin and cypermethrin EW, *Btk* and trichlorfon to control *M. plana* larvae (Table 4). Moreover, all these insecticides provided reasonable results and were suggested for the control of *M. plana* at 14 DAT to 30 DAT using the ground spraying technique. Our findings were in agreement with the results of Chung and Narendran (1996) and Kok *et al.* (2012), who reported that cypermethrin was the most cost effective treatment against bagworm infestation.

In contrast, the application of trichlorfon was the most expensive treatment among the insecticides tested. Similarly, Chung (1998) found also that trichlorfon was more expensive than other treatments such as cypermethrin and cyhalothrin. However, a survey conducted by Basri *et al.* (1988) on 49 plantations in peninsular Malaysia showed that trichlorfon was the most commonly used insecticide for ground spraying in Malaysia for controlling bagworm infestations. Basri and Norman (2002) reported that the cost of *Bt* application by using the MPOB SRBT1 product was only RM 90 per treatment; however, the cost could be doubled if a follow-up treatment were needed.

Table 3: Operational productivity of the ground spraying technique to control the *M. plana* in oil palm plantation based on the time consumed per application.

Replicate	Spray duration (hour)	
	Per application	Per hectare*
R1	7.00	4.55
R2	7.33	4.77
R3	6.67	4.33
R4	6.67	4.33
Total (hour)	27.67	17.98
Mean (hour)	6.92	4.50
SE	0.28	0.18

Note: *Estimated calculation based on 130 palms/hectare.

Table 4: Cost estimation of insecticide application to control *M. plana* in oil palm plantation using the ground spraying technique.

Treatments	Dosage/ ha	Cost (in RM)/ha			
		Price	Labour *	Consumables **	Total cost
Btk	0.80 L	40.00	45.00	15.40	100.40
Trichlorfon	1.63 kg a.i.	97.80	45.00	15.40+17.00	175.20
Lambda-cyhalothrin	0.65 L	28.60	45.00	15.40+17.00	106.00
Cypermethrin (EC)	2.21 L	23.21	45.00	15.40+17.00	100.61
Cypermethrin (EW)	1.10 L	33.00	45.00	15.40+17.00	110.40

Notes: RM = Ringgit Malaysia (1 $USD = RM 3.20, 2012); ha = hectare; a.i. = active ingredients; L = litre; *labour cost RM 15.00 for each worker per day; **consumable cost + stickers.

CONCLUSION

We found that the application of trichlorfon, cypermethrin and lambda-cyhalothrin at recommended doses were all effective insecticides to control *M. plana* larvae in an oil palm plantation in Malaysia. In general, insecticide application using the ground spraying technique effectively suppressed larval population of *M. plana*. The application of *Btk* gave unsatisfactory results and is not suggested for reducing the larval population of *M. plana* below the ETL. Ground spraying using a power sprayer with a high volume of water was not appropriate for *Btk* application. In addition, the ground spraying technique using a power sprayer was of low productivity and consumed more time. This technique is not appropriate for controlling bagworms in large areas. Thus, ground spraying using a power sprayer is recommended only in infested areas (less than 50 ha). The *Btk* treatment was the most cost-effective control, but was not adequately effective against *M. plana* in a single treatment. Follow-up treatments were suggested to reduce the larval population below the ETL. However, follow-up treatments are not cost-effective due to increased treatment cost. Further laboratory and field studies are urgently needed to improve bagworm control on oil palm plantations. Several procedural parameters (applied concentrations, the delivery of active ingredients, spraying techniques and environmental conditions) remain to be optimised in future studies of *Btk* in the management of *M. plana*.

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