Research Article

Optimization of Motorized Backpack Mistblower for Efficient Application of Insecticides against the Bagworm, *Metisa plana* Walker

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Abstract | Oil Palm (*Elaeis guineensis* Jacq.) is a crucial economic crop in Malaysia which has become susceptible towards pests and diseases. Studies showed the major leaf defoliator of oil palm in Malaysia is the bagworm, *Metisa plana*. Various spraying methods had been developed for controlling the bagworms. A ground study was conducted in FELDA Gunung Besout 04, Perak, with its main focus on mistblower application towards bagworms. Stihl SR420 mistblower was characterised by having 1.2L / min flow rate, produced volume median diameter of 80µm, and achieved spraying productivity of 2.58 hectares' land size (approximately 350 oil palms) per man day. The study was to evaluate the efficacy of chlorantraniliprole (Altacor® 34.9WG), *Bacillus thuringiensis kurstaki* (DiPel® ES), cypermethrin (Hextar Cyper 5.5EC), flubendiamide (Takumi® 20WG) and *B. thuringiensis* MPOB Bt-1 (Ecobac-1 EC). The insecticides application rate was based on the manufacturer's recommendation. The bagworms were monitored before treatment and at 3, 7, 15, 30, 45, and 70 days after treatment (DAT). Post-census showed that all insecticides were able to reduce the bagworm population below the economic threshold level (10 larvae/ frond) within 15 DAT. Both cypermethrin and MPOB Bt1 resulted in the highest mortality of bagworms which was 83%. Then, flubendiamide, chlorantraniliprole and Btk resulted in mortality rate of 82%, 75%, and 70% respectively. All aforementioned, insecticides applied were able to suppress the population up to 30 DAT.

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Introduction

Oil palm (Palmae: *Elaeis guineensis Jacquin*) was originated from West Africa and brought into South-East Asia early of the 20th Century. It was first introduced as an ornamental plant in Malaysia, originated from Bogor, Indonesia (Arnott, 1963). Oil palm is one of the major crops in Malaysia yielded threefold oil more than coconut (Nair, 2010). The development of agricultural industry has improved people socioeconomic and lifestyle progressively. In 2016, total oil palm planted area was 5.74 million hectares, with 12.3% planted area belongs to FELDA Malaysian Palm Oil Board (MPOB, 2016). One of the major pests attacking oil palm severely is leaf-eating caterpillars for example bagworm, neetle and moth caterpillars. The bagworm, *Metisa plana*, is a significant leaf defoliator in Malaysian oil palm plantations (Basri *et al*., 1988). *Metisa plana* causes damage by feeding on young leaves of oil palm. The infestation may happen rapidly since their life cycle are shot thus reproduction rates are high (Priwiratama *et al*., 2018). Moderate defoliation by bagworm can cause declining in yield around 30-

40% at the first year and second year after defoliation (Basri,1993; Kamarudin and Wahid, 2010; Potineni and Saravanan, 2013).

Chemical control has been used widely to prevent outbreak and to lower the bagworm population below economic threshold level (ETL). ETL is a condition where pest population density should be managed from increasing and contributing to economic dropping (Stern *et al*., 1959; Higley and Boethel, 1996). The advancement of Integrated Pest Management (IPM) encourages the use of selective chemicals on target pests while maintaining the safe of natural enemies (Wood,1971). Chemical control is speedy and practical to defeat the *M. plana* during the population outbreaks (Yap, 2000). There are numerous ways for applying insecticides towards the oil palm such as ground spraying, trunk injection, aerial spraying and root absorption. Usually, knapsack sprayer will be used to control bagworm populations by spraying the pesticides from the ground (Sudarsono *et al*., 2011). In combating bagworms, ground spraying provides higher spray deposition compared to aerial application whereas increasing in plant height can reduce the tendency of spray deposition (Nansen *et al*., 2011). Study in optimising the handling of motorized backpack mistblower and efficacy of applied insecticides using mistblower against *M. plana* in the field should be conducted to reduce *M. plana* population in the young oil palm plantation. In addition, two novel insecticides comprising of chlorantraniliprole and flubendiamide that believed to have a potential of controlling *M. plana* and environmentally friendly will be assessed throughout this study.

Materials and Methods

The study was conducted at FELDA Gunung Besout 04 oil palm plantation located in Sungkai, Perak with the total area of 878.11 hectares. The average age of oil palm was six years old and heights vary within 6 to 7 metres. Three areas were selected, separated by geographical terrain. Each area selected was divided into six treatment plots including a control plot (Figure 1). Each treatment plot consisted of 72 palms and another two rows as buffer zone.

Stihl SR 420 Motorised Backpack Mistblower was used for the spraying application. Proper calibration was conducted to evaluate the spraying pattern, spraying duration, best nozzle restrictor and the flow rate of mistblower. Each insecticides usage for spraying application was according to the manufacturer's recommendation rates (Table 1). Each solution was added with surfactant of Miracle S240™ and fluorescence tracer at 0.0025% w/v. Formula for pesticide spray as below (Mazuan, 2018).

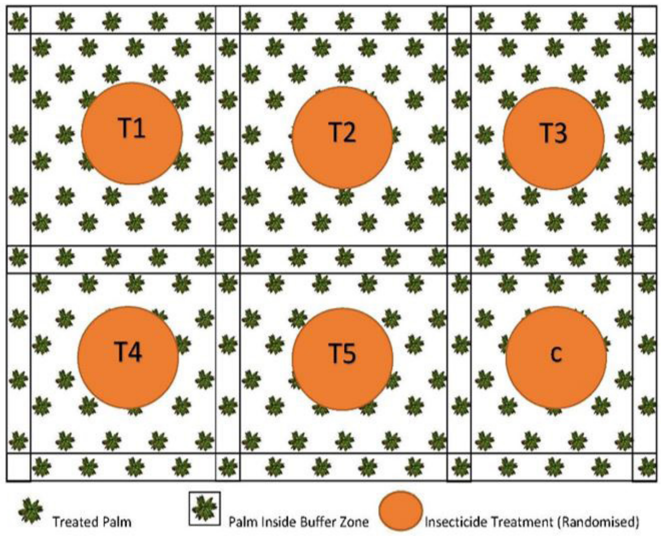

Figure 1: *Experimental design in RCBD for one block area (consisted of 432 palms).*

Table 1: *Insecticides and recommendation rates per hectare.*

Treatment code	Active Ingredient (A.I)	Manufacturer's brand	Recommended Rate/ ha
T1	Chlorantraniliprole	Altacor® 34.9 WG	60g
T2	B. thuringiensis kurstaki	DiPel® ES	1L
T3	Cypermethrin	Hextar Cyper 5.5EC	1L
T4	Flubendiamide	Takumi® 20WG	100g
T5	*B. thuringiensis* MPOB Bt1	Ecobac-1 EC	3L
T6	Water	Control	-

Spray volume (L/ha)= flow rate (L/min) x Spray duration in one hectare (min/ha)

Spraying application= Recommended insecticide (unit/ hectare) x spray volume (L/hectares)

The efficacy of insecticides was evaluated by assessing the number of *M. plana* before treatment application in comparison to post-treatment. Post-treatment census was conducted at 3, 7, 15, 30, 45 and 60 days. The census of bagworm was conducted by pruning one frond or the upper frond that had sign of bagworm attack with inclination of 45°. According to best practice, bagworm attack will be clearly shown at frond number 17 and thus it will be selected for pruning. Subsequently, the number of *M. plana* was counted on every surface of the frond according to larval stages. Upon the completion of spray treatment, sampling made by randomly select one leaf from each frond section at proximal, middle and distal from three scattered trees at each sprayed area. The collected samples were analysed for spray deposition by using fluorometer. Analysis of Variance (ANOVA) was used to examine the collected data at p=0.05. Tukey's multiple range test was used to further distinguish the means in SAS computer package (SAS 9.4).

Results and Discussion

Spraying application with Stihl SR420 mistblower was conducted based on 110L spray volume, 40 seconds spraying time and restrictor 3. It was concluded that vertical zig-zag movement following the frond shape was the optimum technique to maximise the droplet distribution (Mazuan, 2018). Mist spraying followed by constant vertical direction towards the frond provides maximum coverage of droplet distribution towards the target area, thereby minimising the impact towards non-targeted insects. 1.2L per minutes flow rate was produced with the volume median diameter (VMD) of 80µm (very fine droplet) (Table 2). A worker was estimated to spray at 3.1 hours per hectare (10 minutes for refill and resting time) and projected to cover 2.58 hectares in one day. A team of five sprayed roughly 13 hectares per day which equivalent to 77.4 hectares per week (Mazuan, 2018).

Table 2: *Calculation of mistblower application per man day.*

Sprayer	Tank size	Litre per hectares	Flow rate (L / min)
Mistblower Stihl SR420	12 L	110 L	1.20 ± 0.006
Time needed to spray one hectare	Number of refill		Time needed for refill + resting time
1.53 hours	10		10 minutes
Overall time spray / hectares	3.1 hours		
Working hours	8 hours		
Total areas covered (man day)	2.58 hectares		

Standard curve of fluorescence concentration was plotted to determine the fluorescence concentration based on the fluorometer reading. The mean concentration of spray depositions (Table 3) showed that there is no significant difference between each treatment (F=1.94, d.f=4, P =0.1073). Therefore, the results showed that the distribution of droplets was constant on all the treatment plots (Figure 2).

Table 3: *Mean concentration of spray deposition in each treatment plot.*

Treatment	Mean Concentration ($\mu g l^{-1}$) ± SE
Cypermethrin	$5.01 \times 10^{-4} \pm 1.70 \times 10^{-4}$
B. thuringiensis kurstaki	$3.82 \times 10^{-4} \pm 3.64 \times 10^{-5}$
Flubendiamide	$7.75 \times 10^{-4} \pm 1.08 \times 10^{-4}$
B. thuringiensis MPOB Bt1	$3.97 \times 10^{-4} \pm 1.03 \times 10^{-4}$
Chlorantraniliprole	$6.04 \times 10^{-4} \pm 1.03 \times 10^{-4}$
F value	1.94
P value	0.1073

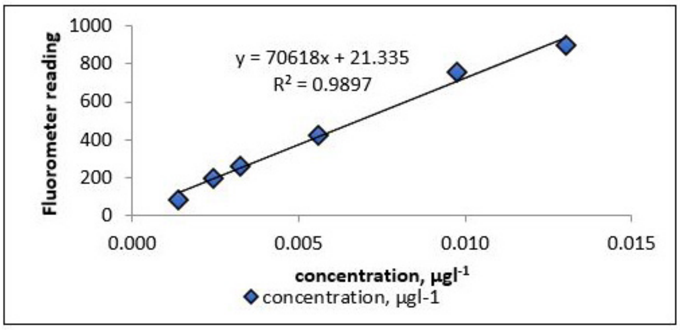

Figure 2: *Standard curve of fluorescence concentration.*
Note: *Mean followed by similar letter in the same column are not significantly different after Tukey's multiple test at 95% confidence level. Number in brackets are the percentage reduction of bagworm (%) on selected DAT.*

Bagworm census is a core activity need to be conducted in every bagworm's attack. The purpose is to identify the bagworm species, and to monitor the attacked-infestation area. Pre-assessment was conducted in the study area to find the suitable period in which the bagworm larvae were within early instars to improve reliability of the result. Therefore, *M. plana* was shown to be dominant, and only the species that was counted and recorded for this experiment. Based on the census conducted, the means number of *M. plana* among the treatment was significantly different at various assessment days (Table 4).

The population of *M. plana* was shown to have a significant reduction in all treatment plots as early as 3 DAT. The mortality rate of *M. plana* shown the highest at chlorantraniliprole (50%), as compare to rest of other treatments. Population of *M. plana* had showed a slight reduction in control plot by 2%. Means population in treatment plot was significantly different to each other (F = 6.60, d.f= 5, P < 0.001).

The population of *M. plana* had reduced below Economic Threshold Level (ETL) at 15 DAT for all the evaluated insecticides. Population declined was shown to be at approximately 80% from the initial number before the treatment. The ETL showed a sign of critical level for the maximum number of bagworm's larvae to live underneath of one frond. The ETL for bagworm species of *M. plana* is 10 larvae per frond. Natural enemies were sufficient to control the population from outbreak occurrence, given usual ecological practises, so the population counted below the ETL was considered negligible (Wood, 1971; Hoong and Hoh, 1992).

The population of *M. plana* remained below ETL at 30 DAT (Figure 3). However, showed sign of population growth at 45 DAT for chlorantraniliprole and Btk. Nonetheless, the population of *M. plana* in flubendiamide, cypermethrin and MPOB Bt-1 was keep dropping, and remained below ETL. The highest mortality rate of *M. plana* was flubendiamide (97%) followed by cypermethrin (95%), MPOB Bt1 (87%), chlorantraniliprole (70%) and Btk (62%). Population in control plot was maintained above the ETL. Mortality of the bagworm's population was observed in the control plots, which can be assumed due to the biotic and abiotic factors. The biotic factors exemplified as various beneficial insects that acted as predators or parasitoids to the bagworms larvae or adults.

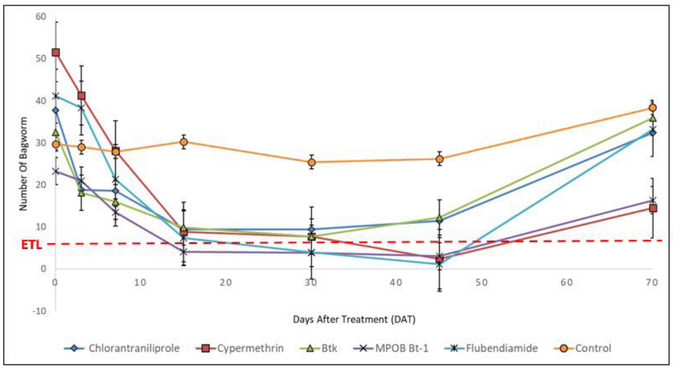

Figure 3: *The mean number of bagworms over days of treatment.*
Note: *Economic Threshold Level (ETL) of 10 larvae/ frond (Wood,1971; Hoong and Hoh, 1992).*

Bagworm management may be aided by biological control using natural enemies such as bacteria, parasitoids, and predators (Ramlah *et al*., 2003; Cheong *et al*., 2010). For instance, various biological control agents such as *Cotesia* (=*Apanteles*) *metesae, Cosmelestes picticeps* (Hemiptera: Reduviidae) and *Dolichogenidea metasae* (Hymenoptera: Braconidae) were applied to manage the bagworms.

Table 4: *Mean population and percentage mortality of M. Plana at each DAT after treatment application.*

Treatment (Active ingredient)	Means population of m. plana over day of treatment						
	Pre-census	3 DAT	7 DAT	15DAT	30DAT	45DAT	70DAT
Chlorantraniliprole	37.77±4.05 abc	18.83±2.27 b	18.63±2.04 ab	9.37±4.17 b	9.43±0.47 b	11.47±0.42 b	32.40±5.81 ab
		(50%)	(51%)	(75%)	(75%)	(70%)	(14%)
Bacillus thuringiensis kurstaki	32.50±3.16 bc	18.17±1.77 b	15.93±1.59 ab	9.83±3.55 b	7.73±0.63 bc	12.20±0.59 b	35.93±4.42 a
		(44%)	(51%)	(70%)	(76%)	(62%)	11%
Cypermethrin	51.60±5.26 a	41.27±4.52 a	28.17±4.56 a	8.83±4.87 b	7.67±1.03 bc	2.33±0.63 c	14.47±4.34 c
		(20%)	(45%)	(83%)	(85%)	(95%)	(72%)
Flubendiamide	41.13±6.45 ab	38.30±5.94 a	21.30±3.98 ab	7.37±6.75 b	4.00±0.79 c	1.10±0.39 c	33.20±3.02 a
		(7%)	(48%)	(82%)	(90%)	(97%)	(19%)
Bacillus thuringiensis MPOB Bt1	23.27±5.79 c	21.00±3.89 b	13.43±2.17 b	4.07±5.86 b	3.80±1.01 c	3.03±0.91 c	16.33±2.88 bc
		(10%)	(42%)	(83%)	(84%)	(87%)	(30%)
Control	29.67± 2.98 bc	28.97±3.34 ab	27.93±3.71 a	30.23±3.13 a	25.43±1.56 a	26.23±1.24 a	38.37±2.74 a
		(2%)	(6%)	2%	(14%)	(12%)	29%
F value	3.69	6.60	3.15	37.45	47.49	71.51	6.78
P value	0.0034	0.001	0.0094	0.001	0.001	0.001	0.001

Cheong *et al.* (2010) reported despite the fact that entomopathogenic fungi such as *Paecilomyces fumosoroseus* and *Metarhizium anisopliae* have shown promising results in the laboratory, when used in the field, these EPF provided mixed results. In Perak, Malaysia Cheong *et al.* (2010) discovered predators were the leading cause of bagworm natural mortality, followed by parasitoids and fungal infections, with 37.0 percent, 35.9%, and 27.2 percent, respectively, suppressing the bagworm population in the region.

At 70 DAT, all plots displayed a significant increase of population *M. plana* above the ETL. The rapid increased of *M. plana* population after the treatment showed that the biotic factors were unable to supress the existing population below the ETL. The reason may be due to the high application of broad-spectrum insecticides and a low number of beneficial plants in the field, which could damage the natural ecological of micro-environment.

The occurrence of multi-stages (instar) of larvae in study location might be another reason of recurring outbreak. Supposedly, the second treatment in the same area should be conducted at 45 DAT to control remerging of the population from late instar. The result of cypermethrin was the best among others but the broad-spectrum characteristic may damage the natural beneficial predators and parasitoids. Pyrethroids, on the other hand, have been designated as the most harmful insecticides to beneficial anthropods (Croft, 1990). Overall, nymphs of the predator were highly susceptible to the insecticides of cypermethrin, deltamethrin and dipterex (Farehan *et al*., 2013). The use of *Bacillus thuringiensis* however provided less adverse effect on the beneficial insects. Study conducted by Najib *et al.* (2009) showed that When high dose Bt-Teracon-1® was administered to beneficial insects associated with *Cassia cobanensis*, it resulted in 25% mortality compared to 100% mortality when cypermethrin was used. As a result, *B. thuringiensis* was chosen because it has less side effects and has been shown to be pest specific.

Nonetheless, the existence of novel insecticides based on diamine class such as chlorantraniliprole and flubendiamide, provided a specific mode of action to Lepidopteran species. They can be the alternatives to biological insecticide *B. thuringiensis* because of the weakness of short life span, and easily degraded to the sunlight (Valent BioScience Corporation, 2014).

Conclusions and Recommendations

The study showed that the application of chlorantraniliprole, flubendiamide, Btk, MPOB Bt1 and cypermethrin were effective to control the population of *M. plana* significantly below the ETL of 10 larvae per frond within 15 DAT. Cypermethrin and MPOB Bt1 were recorded as the highest mortality of *M. plana* by 83%, followed by flubendiamide, chlorantraniliprole and Btk. The insecticides were able to suppress the population of *M. plana* up to 30 DAT. However, *M. plana* population was increased slowly after 30 DAT indicated the second treatment should be applied to control the emergence of new larval population. The use of cypermethrin however, could potentially kill the beneficial insects and natural enemies of *M. plana*. Whilst *B. thuringiensis* was proven to be the pest-specific. Nevertheless, the novel chemical insecticides such as chlorantraniliprole and flubendiamide were claimed to be specific to Lepidopteran. Therefore, further study was suggested in observing the impact of these insecticides on beneficial insect *E. kamerunicus*, which was highly susceptible to the insecticides.

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Novelty Statement

Our study provides insightful and relevant data of two novel insecticides; chlorantraniliprole and flubendiamide against lepidopteran species at the field. Based on this study, both insecticides are promising alternatives to biological insecticides B. thuringiensis.

Author's Contribution

Syed Mazuan and Syed Mohamed: Conceived the idea. Wrote abstract, methodology, data collection and analysis. Introduction, result, discussion, conclusion.
Insyirah Ishak: Overall management of the article. Abstract, conclusion, references
Dzolkhifli Omar: Conceived the idea. Technical input.
Norhayu Asib: Conceived the idea, Overall

management of the article and technical input.

Conflict of interest

The authors have declared no conflict of interest.

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