The efficacy of single and double tank thermal fogging tool of Bacillus thuringiensis application in oil palm

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Abstract. Many oil palm planters argue that the application of Bacillus thuringiensis through fogging can only be conducted using double-tank fogging equipment. It was believed that the use of single-tank fogging will be resulting in low efficacy. The study aimed to evaluate the efficacy of single and double-tank fogging machines trial of B. thuringiensis in oil palm plantations. Two doses of application, i.e., 0.5 L/ha and 1 L/ha, were tested using each fogging machine. A plot of mock fogging application was used as a control treatment. The result showed that B. thuringiensis have high efficacy against Mahasena corbetti. More than 90% of larva mortality was observed at 14 days after application via a single-tank and a double-tank fogging machine. This result suggests that a single-tank fogging machine could be used for B. thuringiensis application without reducing its efficacy against target pests.

Keywords: efficacy rate, Mahasena corbetti, mortality rate, fogging machine

1. Introduction
Mahasena corbetti is one of the common bagworms which attack oil palm. This bagworm causes leaf damage with a very high defoliation rate [1,2]. M. corbetti attack also becomes a serious problem because, in addition, eaten the leaves, this bagworm also cut the leaves to serve as a bag. Severe damage could result in 40-60% production loss in the second year after the attack [3]. The bagworms attacks occur at all palm ages, but the highest attack rate occurs in palms over eight years because, at this age, the fronds were closed by other fronds in the next palm, which can facilitate the distribution of this bagworm. The signs of M. corbetti attack on palm leaves were skeletonized and looked like a burn. In the first instar, the larvae ate in the upper epidermal layer, whereas the final stage larvae ate in the bottom epidermis [2]. M. corbetti has the highest consumption rate (4 cm² / day) and the highest critical population level than other bagworms, with up to five larvae per frond [3].

The common control methods of these bagworms were limited by using synthetic chemical insecticides. The use of synthetic chemical insecticides is preferred because it is faster to control pest populations and easy to use [4]. However, the use of synthetic Insecticides continuously is very unwise and could cause various negative impacts on the environment. In addition, the problems of oil palm pests are also becoming more complicated, such as the existence of pest resistance, pest resurgence, the death of natural enemies. Synthetic chemical control is now being reduced due to its adverse effects. Biological control is one way out of this problem. Technically, controlling with biological insecticide is as good as with chemical control because effective and efficient also environmentally friendly [5].

However, biological agents usually have a low mortality rate if applied to control pests in oil palm over eight years due to the use of a single tank fogger. This is a limiting factor that causes biological
agents mixed with diesel, resulting in death. The heat from the fogging machine was thought to damage and kill biological agents, so these two factors can reduce the effectiveness of the control. Bio-insecticide testing is needed to obtain a higher control result, which can be used on single and double tank foggers and testing for its efficacy against target pests and its compatibility rate with fogging applications. *Bacillus thuringiensis* is a biological insecticide that has high effectiveness for the caterpillar larvae of the Lepidoptera order. This test is in addition to knowing its efficacy against bagworms *M. corbetti*, also intended to prove *B. thuringiensis* is a biological insecticide that could be applied using the fogging method.

2. Materials and methods

2.1. Location
The research was conducted in 8-years-old oil palm plantation in Simalungun Regency, North Sumatra Province. The experimental design used was Randomized Block Design with five treatments and ten replications. The type and dose of the insecticide used in this test are listed in Table 1.

| No. | Biological agents     | Formulation             | Dose (ml/ha) | Type of Fogger |
|-----|-----------------------|-------------------------|--------------|----------------|
| 1.  | *B. thuringiensis*     | Suspension Concentrate  | 500          | Single tank    |
| 2.  | *B. thuringiensis*     | Suspension Concentrate  | 1000         | Single tank    |
| 3.  | *B. thuringiensis*     | Suspension Concentrate  | 500          | Double tank    |
| 4.  | *B. thuringiensis*     | Suspension Concentrate  | 1000         | Double tank    |
| 5.  | Untreated (UTC)        | -                       | -            | -              |

The treatment plot consists of twelve palms with five palms in the middle used as treated palms (Figure 1). The treatment plots were separated by four rows of oil palm. It is intended to prevent contamination between treatments. The arrangement of plot treatment was determined based on preliminary observations on the bagworm population of the sample palms. Each sample palm was observed to measure the population of *M. corbetti* on the top, middle, and bottom fronds of the treated oil palm. The initial bagworm population before treatment in all treatments was equal or nearly equal.

![Figure 1](image-url). Layout plot treatment of field trial in efficacy test of *Bacillus thuringiensis* dosages using two types of fogging machine on oil palm plantations in Simalungun Regency, North Sumatra Province.
2.2. Efficacy test
To determine the effect of treatment on target, observation of survival bagworm at 3, 7, 14, 17, and 21 days after application, then calculated the percentage of mortality or percentage of population decline. The data were analyzed using ANOVA and Tukey Honestly Significant Difference test, with the differences were considered significant at P-value < 0.05. The efficacy rate calculated using the Abbott formula [6]:

\[ E_l = \frac{(C_a - T_a)}{C_a} \times 100\% \]

\( E_l \) = Insecticide efficacy
\( T_a \) = Pest populations or damage percentage in insecticide treatment plots after insecticides application.
\( C_a \) = Pest populations or damage percentage in control treatment plots after insecticides application.

2.3. Efficacy criteria
The insecticidal formulation was effective when at least (1/2n+1) times of observation (n = total number of observations after application), the insecticide efficacy level (EI) = 50% [6]:
- The pest population on the treated plots was lower or not significantly different from the comparative insecticidal plots (5% level)
- The pest population in the treated plots was significantly lower than the control pest population (5% level).

3. Results and discussion
3.1. The mortality rate
The preliminary observations on the \( M. \) corbetti populations of each sample palm were observed on the top, middle, and bottom fronds. Three sections of the frond, lower, middle, and upper were designed to get the information about the fog that could bring the biological agents for covered all levels of fronds. The bagworm population in all treatments was equal or nearly equal. The average population of \( M. \) corbetti in all samples reaches 52.69 larvae per frond (Table 2).

Table 2. The initial population of \( Mahasena \) corbetti in efficacy test of \( Bacillus \) thuringiensis dosages using two types of fogging machine on oil palm plantations in Simalungun Regency, North Sumatra Province.

| No. | Products    | Dosages          | Initial population |
|-----|-------------|------------------|--------------------|
| 1.  | \( B. \) thuringiensis | 500 ml/ha Single tank (500K1) | Upper 36.90, Middle 57.40, Lower 54.50 |
| 2.  | \( B. \) thuringiensis | 1000 ml/ha Single tank (1000K1) | Middle 64.00, Lower 39.40, Upper 60.40 |
| 3.  | \( B. \) thuringiensis | 500 ml/ha Double tank (500K2) | Middle 65.00, Lower 67.70, Upper 64.60 |
| 4.  | \( B. \) thuringiensis | 1000 ml/ha Double tank (1000K2) | Middle 36.50, Lower 25.60, Upper 51.60 |
| 5.  | Untreated (UTC) | - | Middle 53.60, Lower 61.20 |
3.2. The mortality rate in lower fronds
The application dose of all fogging treatments showed significantly different with untreated (UTC). The 500K1 treatment was the lowest mortality rate in all fogging treatments which was also significantly different from 1000K1, 500K2, and 1000K2 treatments. Meanwhile, in 7 days after application, each fogging treatment was not significantly different (Table 3). The mortality in all treatments was growth every observation. The mortality at 14 days after application reached > 90% in all treatments and reached 100% in 28 days after application (Figure 2).

Table 3. ANOVA results on the mortality rate of M. corbetti on the lower frond in efficacy test of Bacillus thuringiensis dosages using two types of fogging machine on oil palm plantations in Simalungun Regency, North Sumatra Province.

| Treatments | 3   | 7   | 14  | 17  | 21  | 28  |
|------------|-----|-----|-----|-----|-----|-----|
| 500K1      | 34.50 b | 51.93 a | 99.82 a | 100.00 a | 100.00 a | 100.00 a |
| 1000K1     | 62.18 a | 73.10 a | 99.75 a | 100.00 a | 100.00 a | 100.00 a |
| 500K2      | 54.80 a | 72.08 a | 99.26 a | 99.85 a | 99.85 a | 100.00 a |
| 1000K2     | 69.15 a | 82.03 a | 90.63 a | 94.53 a | 97.27 a | 100.00 a |
| UTC        | 1.31 c  | 2.29 b  | 2.94 b  | 4.90 b  | 8.17 b  | 10.13 b |

Note: Small letter beside the mean denotes the statistical difference between a location, based Tukey pairwise comparison (P-value < 0.05).

Figure 2. The mortality rate of bagworm on the upper frond in efficacy test of Bacillus thuringiensis dosages using two types of fogging machine on oil palm plantations in Simalungun Regency, North Sumatra Province.

3.3. The mortality rate in middle fronds
The mortality percentage in 500ml/ha using a single tank was lower than 1000 ml/ha using a double tank fogging machine. The mortality rate of all fogging treatments in the middle frond showed significantly different with untreated (UTC) (Table 4). The application of B. thuringiensis with dose 500ml/ha using single and double tank fogger does not give high mortality due to the fog that carries B. thuringiensis was unable to reach optimal covered the middle fronds compared to the lower fronds. The
The highest bagworms mortality rate at the middle fronds in 1000 ml/ha doses treatment using single tank fogging machine in every observation. All treatments reached > 90% at 14 days after application (Figure 3).

Table 4. ANOVA results on the mortality rate of *M. corbetti* on the middle frond in efficacy test of *Bacillus thuringiensis* dosages using two types of fogging machine on oil palm plantations in Simalungun Regency, North Sumatra Province.

| Treatments | Days after application |
|------------|------------------------|
|            | 3 | 7 | 14 | 17 | 21 | 28 |
| 500K1      | 40.42 a | 55.75 a | 99.48 a | 100.00 a | 100.00 a | 100.00 a |
| 1000K1     | 68.13 a | 81.56 a | 100.00 a | 100.00 a | 100.00 a | 100.00 a |
| 500K2      | 43.69 a | 66.92 a | 97.08 a | 97.85 a | 99.23 a | 100.00 a |
| 1000K2     | 53.70 a | 67.12 a | 94.52 a | 96.16 a | 98.36 a | 100.00 a |
| UTC        | 1.12 c | 2.24 b | 3.36 b | 5.97 b | 7.84 b | 10.07 b |

Note: Small letter beside the mean denotes the statistical difference between a location, based Tukey pairwise comparison (P-value < 0.05).

Figure 3. The mortality rate of bagworm on the middle frond in efficacy test of *Bacillus thuringiensis* dosages using two types of fogging machine on oil palm plantations in Simalungun Regency, North Sumatra Province.

3.4. The mortality rate in upper fronds

Based on the observation, 500K1, 1000K1, and 1000K2 treatments were significantly different with untreated (UTC) in three days after application. While treatment 500K2 was not significantly different with UTC, it means control application *B. thuringiensis* with dose 500ml/ha using the double tank fogger does not give high mortality in early observation (Table 5). The highest bagworms mortality rate at the upper fronds in 1000 ml/ha doses treatment, either in the single or double tank. All treatments reached > 90% at 14 days after application (Figure 4). The same results in the middle frond were found in the mortality rate of treatment 500K2 which is lower than other treatments in the upper frond.
Table 5. ANOVA results on the mortality rate of *M. corbetti* on the upper frond in efficacy test of *Bacillus thuringiensis* dosages using two types of fogging machine on oil palm plantations in Simalungun Regency, North Sumatra Province

| Treatments | Days after application |
|------------|------------------------|
|            | 3     | 7     | 14    | 17    | 21    | 28    |
| 500K1      | 49.59 a | 67.21 a | 99.73 a | 99.73 a | 100.00 a | 100.00 a |
| 1000K1     | 67.12 a | 76.92 a | 99.42 a | 100.00 a | 100.00 a | 100.00 a |
| 500K2      | 27.32 ab| 59.11 a | 95.53 a | 97.19 a | 98.68 a | 100.00 a |
| 1000K2     | 60.37 a | 70.90 a | 93.50 a | 96.13 a | 97.83 a | 100.00 a |
| UTC        | 0.00 b  | 1.16 b  | 3.49 b  | 5.04b  | 8.53 b  | 10.85 b  |

Note: Small letter beside the mean denotes the statistical difference between a location, based Tukey pairwise comparison (P-value < 0.05).

Figure 4. The mortality rate of bagworm on the upper frond in efficacy test of *Bacillus thuringiensis* dosages using two types of fogging machine on oil palm plantations in Simalungun Regency, North Sumatra Province.

The results on the lower, middle, and upper fronds showed that the height of the frond had a major influence on the mortality rate of larvae. The mortality rate of larvae in three days after application showed that the lower frond had the highest mortality rate, followed by the middle and upper frond with the mortality rate reached 55.25%, 51.48%, and 51.10%, respectively. The lower frond met the fog, which contained *B. thuringiensis* in high quality and quantity earlier than others, while the middle and upper frond gets less fog and lasts longer. The upper frond gets less fog because of disturbances from wind, and the lower density of the frond could not hold the fog longer. In addition, the mixing factor also greatly affects the effectiveness of a spray solution. The homogeneous spray solution will give maximum results. The fogging application was strongly influenced by the homogeneity of the spray solution, the determination of the active ingredients, the fogging machine, and the weather conditions when fogging applications [7].

The type of fogging machine and the dose also affect the mortality rate, the single tank fogger with a dose of 500ml/ha and 1000 ml/ha was able to control insect populations up to 95% in the lower, middle and upper fronds at 17 days after application and reach 100% mortality rate in 21 days after application. Meanwhile, fogging application using double tank fogging machine with 500 ml/ha and 1000 ml/ha
doses reach 100% mortality rate in 28 days after application. Treatment 1000K2 has the lowest mortality rate in 14, 17, 21 days after application. The finding showed that the bagworms control using B. thuringiensis with suspension concentrate formulation could be carried out with single tank and double tank foggers, using doses of 500 ml/ha and 1000 ml/ha.

3.5. The efficacy rate
The efficacy rate of B. thuringiensis at 14 days after application showed that all treatments had an efficacy rate > 90% in each frond section. The 500K1 and 1000K1 treatments reached a 100% efficacy rate at 17 days after application in the lower fronds (Figure 5). The same results were also shown in the middle fronds at 500K1 and 1000K1 treatments, which reached a 100% efficacy rate at 17 days after application (Figure 6). Meanwhile in the upper frond, the 500K1 and 1000K1 treatments reached a 100% efficacy rate at 21 days after application (Figure 7). The efficacy rate of 500K2 and 1000K2 reached a 100% at 28 days after application in all frond sections. Based on the insecticide efficacy rate, the efficacy rate of all B. thuringiensis treatments has exceeded the minimum insecticide efficacy rate, which is more than 50% at seven days after application.

Figure 5. The efficacy rate B. thuringiensis on the lower frond on oil palm plantations in Simalungun Regency, North Sumatra Province.
Based on these results, the *B. thuringiensis* treatment at 500 and 1000 ml/ha doses shows high effectiveness for controlling the population of *M. corbetti* in oil palm plantations. These results also indicated that *B. thuringiensis* products sold in the market could be applied with a single tank or double tank fogging machine. The use of *B. thuringiensis* as biological control is one of the findings that could be more environmentally friendly. Currently, *B. thuringiensis*-based products are cry-crystal proteins that are more heat resistant and water-soluble [8].

The *B. thuringiensis* could control *M. corbetti* quickly when pest populations outbreak and prevent further damage to oil palm leaves. The use of *B. thuringiensis* to control bagworms in Malaysia was quite effective and was reported to reduce the bagworm population by up to 89% [9]. *B. thuringiensis* have bacterial protein crystals which produce insecticidal δ-endotoxins. This crystal is a protoxin that works when it dissolves or enters the insect’s gut and turns into an insecticidal polypeptide [10].
active toxins would interact with epithelial cells in the insect’s gut. The *B. thuringiensis* toxin causes the opening hole in the insect gland’s membrane cells, thus disrupting the osmotic balance of the cells. When the osmotic balance disrupted, the cells become swollen, burst, and cause insect death [10, 11]. The initial symptoms when Cry crystals of *B. thuringiensis* were consumed by insect larvae are the larvae become inactive, the feeding stops, vomiting, and the liquid feces. Then, the larvae become mushy and die within a few days. The bacteria will cause insect body contents to become brownish, red, or yellow when decomposed [12, 13].

### 4. Conclusion

*B. thuringiensis* could be applied with the single tank and double tank fogging machines without reducing its efficacy against target pests. The combination of the single tank fogger with low doses was not optimal in control the bagworm. The use of the double tank fogger with low doses can control pests as well as high doses.

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