Efficacy of some plant extracts against mealybugs on cacao

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Abstract. Mealybugs, Planococcus sp. (Hemiptera: Pseudococcidae), are the secondary pest on the cacao plant. However, this pest often infested cacao shoots in the nursery and causes the death of the seedling. Pest control efforts use existing materials plants in Indonesia and are relatively easy to make and adopt by stakeholders. The purpose of this research was to screen the efficacy of some plants extracts against mealybugs on cacao. We researched in the laboratory of pests and diseases, IIBCRI. Mealybugs were collected from cacao plantations and reared in the laboratory. The materials plants used for extraction were Cassia spectabilis leaves, Gliricidia sepium leaves, Cinnamomum burmannii leaves, Allium sativum bulbs, Reutealis trisperma fruits, and Cymbopogon nardus leaves. The methods were spraying the plant extracts on mealybugs directly (KS) and cacao pod (BS). The results showed that all types of oils at a concentration of 5% in the KS and BS methods could kill mealybugs equivalent to deltamethrin. The smallest value of LC50 3 DAT is at the MSW (KS), while at 7 DAT, LC50 7 DAT is at MDG (BS). The fastest LT50 value is at MSW (KS) 5%, while in the BS method, the fastest LT50 value is on the MBKS 5%.

Keywords: Cassia spectabilis, Cymbopogon nardus, Gliricidia sepium, Planococcus sp., Reutealis trisperma

1. Introduction

Mealybug, Planococcus sp. (Hemiptera: Pseudococcidae), is a cosmopolitan pest that attacks numerous types of plants, such as fruit, vegetable, and ornamental plant [1–5]. In cacao plants, mealybugs are still a secondary pest. However, this pest becomes dangerous because it can transmit swollen shoot virus of cacao such as in West African [6–9]. We can detect mealybugs on young and old cacao plants. If this pest attacks the plant while in the nursery, it can cause the death of seedlings. Mealybugs usually are found in cacao pods (74.1%), twigs (13.4%), and flowers (7.4%) [1, 10–12]

Indonesia has numerous potential plant diversities as bioinsecticides, such as Cymbopogon nardus, Cassia spectabilis (ramayana), Gliricidia sepium (gamal), Cinnamomum burmannii, Reutealis trisperma [13–18]. Recently, using citronella oil has been common to control several pests, such as Plutella xylostella [19] and Helopeltis antonii [20]. In addition, a mixture of ramayana and tobacco leaves can control coffee berry borers [21], and cinnamon waste also can control Helopeltis in cacao plants [18]. Indeed, methanol and water extracts of gamal leaves have been utilized to control mealybugs on coffee, cacao, soursop, and papaya plants [22–25].

However, sometimes the manufacture of bioinsecticides base materials is relatively tricky and expensive. For example, the manufacture of crude extracts requires a rotary evaporator to separate filtrate from solvent. In addition, the average price of essential oil is relatively expensive because the content of essential oils in plants is relatively small. Therefore, plant-based materials are needed that are easy to find and easy to make as bioinsecticides to be used by farmers directly. In this study,
cinnamon, gamal, and ramayana oils were made by boiling in vegetable oils [26] and applied by spraying on mealybugs directly and spraying on cacao pods. This study aimed to screen four types of crude extracts and five types of plant oils that can control mealybugs in cacao.

2. Materials and methods
2.1 Rearing and maintenance of Planococcus sp.
We collected mealybugs from infested pods in the IIBCRI cacao plantation, Sukabumi. Mealybugs were reared on pumpkins (Cucurbita moschata). The experiment was conducted in Plant Pest and Disease Laboratory IIBCRI. For insect acclimatization, mealybugs were transferred to cacao pods the day before and then selected those still active for the experiment.

2.2 Plant samples and extractions
This experiment used crude extracts (4 types) and plant oils (5 types) that are: tung oil (Reutealis trisperma) (MBKS), citronella oil (Cymbopogon nardus) (MSW), ethanol crude extract, and oil of ramayana leaves (Cassia spectabilis) (ETDR and MDR), ethanol crude extract and oil of gamal leaves (Gliricidia sepium) (ETDG and MDG), and ethanol crude extract and oil of cinnamon leaves (Cinnamomum burmannii) (ETKM and MDKM) and garlic ethanol crude extract (Allium sativum) (ETBP). Ethanol crude extracts were made by the maceration method following the extraction method proposed by Soesanthy & Samsudin [16]. The oil from the leaves of ramayana, gamal, and cinnamon were prepared by boiling in vegetable oil according to the method used by the Indonesian Agency for Agricultural Research and Development [26].

2.3 Experimental design and treatments
The experiments were conducted in two steps. The first, a screening test from nine types of treatment at the same concentrations (5%) was conducted. Subsequently, the treatments from screening tests that could kill mealybugs more than 70% were selected and evaluated for the lethal concentration (LC50) and lethal time (LT50). The screening test was conducted using two methods: spraying on mealybugs directly (KS) and spraying on cacao pods (BS). The treatments were MBKS, MSW, ETDR, MDR, ETDG, MDG, ETKM, MDKM, ETBP, and SCP (dish soap). Aquadest as a positive control, and deltamethrin 0.1% as a comparison from chemical pesticides. In total, the 24 treatments were replicated 3 times. Each treatment contains 20 mealybugs. The mortalities of mealybugs were examined and recorded every day for 7 days after treatments (DAT). The mean differences between parameters were analyzed using an ANOVA test and if the treatments showed a significant difference, the analysis continued with Duncan post hoc test at α=5%.

From the screening test results, four treatments were obtained for the KS method: MSW, MDKM, SCP, and deltamethrin, whereas on the BS, as follow MSW, MDKM, MBKM, MDR, MDG, dan deltamethrin. The experiments were continued with three concentrations (1%, 3%, 5%) for each plant oil and SCP, and 0.05%, 0.075%, and 0.1% for deltamethrin, replicated five times for the KS and three replicated for the BS. In addition, the number of dead mealybugs were observed every day for 7 DAT and then were analyzed using an ANOVA test and continued with post hoc Duncan test at α=5% if the treatments showed a significant difference. The effectiveness of the treatments in killing the mealybugs was counted as LC50 and LT50, and both were determined using probit analysis. The IBM SPSS Statistics 26 program.

3. Result and discussion
3.1. Plant extracts screening test
The results of the screening test of plant extracts against Planococcus sp. were shown in Table 1. Types of treatments that caused mortality on mealybugs more than 70% in 7 DAT were deltamethrin, MSW, MBKS, MDKM, MDG, MDR, and SCP. The application method of the treatments can affect the mortality response of mealybugs. Treatment by spraying on cacao pods was more effective than spraying on mealybugs directly. Responds mortality of treatments of MDR (BS), MDG (BS), MDKM
(BS), MBKS (BS), MSW (BS), and SCP (KS) were no significant difference to deltamethrin, which can kill mealybugs 100% in 7 DAT.

Table 1. The mortality percentage of Planococcus sp. due to the treatments of plant extracts at a concentration of 5% with spraying on mealybugs directly (KS) and on cacao pods (BS) method at 7 DAT.

| No. | Treatments       | Mortality (%)±d |  | No. | Treatment       | Mortality (%)±d |
|-----|------------------|-----------------|  |     |                |                |
| 1   | MDR (KS)         | 45.00±5.00 ef    |  | 13  | MDR (BS)       | 100.00±0.00 h   |
| 2   | MDG (KS)         | 26.67±5.77 cd   |  | 14  | MDG (BS)       | 100.00±0.00 h   |
| 3   | MDKM (KS)        | 81.67±2.89 g    |  | 15  | MDKM (BS)      | 100.00±0.00 h   |
| 4   | MBKS (KS)        | 28.33±2.89 cd   |  | 16  | MBKS (BS)      | 100.00±0.00 h   |
| 5   | MSW (KS)         | 75.00±5.00 g    |  | 17  | MSW (BS)       | 100.00±0.00 h   |
| 6   | ETDR (KS)        | 35.00±5.00 de   |  | 18  | ETDR (BS)      | 30.00±0.00 de   |
| 7   | ETDG (KS)        | 45.00±13.23 ef  |  | 19  | ETDG (BS)      | 35.00±0.00 de   |
| 8   | ETKM (KS)        | 21.67±10.41 bcd |  | 20  | ETKM (BS)      | 58.33±2.89 f    |
| 9   | ETBP (KS)        | 45.00±10.00 ef  |  | 21  | ETBP (BS)      | 30.00±5.00 de   |
| 10  | SCP (KS)         | 100.00±0.00 h   |  | 22  | SCP (BS)       | 13.33±2.89 abc  |
| 11  | Aquades (KS)     | 8.33±7.64 ab    |  | 23  | Aquades (BS)   | 3.33±2.89 a     |
| 12  | Deltamethrin (KS)| 100.00±0.00 h   |  | 24  | Deltamethrin (BS)| 100.00±0.00 H  |

MSW (citronella oil), MDKM (cinnamon leaves oil), MBKS (tung oil), MDG (gamal leaves oil), MDR (ramayana leaves oil), SCP (dish soap), ETDR (ramayana leaves ethanol extract), ETDG (gamal leaves ethanol extract), ETDKM (cinnamon leaves ethanol extract), ETBP (garlic ethanol extract).

a Standard deviation.
b Duncan notation.

c Dunnett's multiple comparison test.

The result showed that in the BS method, more than 70% of mealybugs mortalities have occurred at the first day on MDG, MDKM, MBKS, and MSW treatments, and in 3 DAT, all mealybugs were dead. Therefore, for MDR treatment, the mortality of mealybugs raised slower, then killed all insects in 5 DAT (Figure 1A). In KS, plant extracts (ethanol extract or oil) affect mealybugs mortality less than 50% until 7 DAT, except for MSW dan MDKM. At the end of the assessment, mealybugs mortality reached 75% for MSW and 81.67% for MDKM (Figure 1B). The chemical pesticide deltamethrin shows a different mortality response of mealybugs. Deltamethrin has caused 100% death in KS on the first day, while in BS, 100% of death because of deltamethrin has occurred at 3 DAT. SCP also showed promising results 100% mortality at 3 DAT. Dish soap water is more effective sprayed on mealybugs directly than sprayed on pods. However, soapy water can damage the wax layer on the surface of the mealybug’s body [2,27]. Furthermore, the mortality responses of mealybugs to all types of ethanol extract were below 70%.

3.2. Selected treatment experiment

Observations results at 7 DAT showed that there were significant differences in mortality percentage due to differences in plant oil types ($F_{(2,52)}=1777.22, p<0.05$) and concentration levels ($F_{(4,22)}=1033.61, p<0.05$) in spraying on mealybugs directly method. Citronella oil exerts no different influence as the chemical compound deltamethrin causes death to mealybugs (Table 2). Unlike in KS, all types of plant oils tested showed no significant difference to deltamethrin ($F_{(4,38)}=926.94, p<0.05$) in BS. Indeed, treatment of gamal leaves oil (97.78±6.21%) caused the highest mortality of mealybugs. Citronella oil contains 81.67% geraniol and 13.95% citronellal [28]. This oil is insecticidal on mealybugs, Plutella xylostella, Helopeltis sp., Conopomorpha cramerella and so on [16, 20, 29]. The crude and pure extract of gamal leaves contain flavonoids that act as stomach poisons [23, 25, 30].
Figure 1. Development of Planococcus sp. mortality due to treatment of plants extracts for 7 DAT.

Table 2 Mortality average of Planococcus sp. due to the treatments of plants oils on spraying on mealybugs directly (KS) and on cacao pods (BS) methods.

| Treatment     | Mortality at 7 DAT (%)± Std. Error a |
|---------------|--------------------------------------|
|               | KS                                   | BS                                    |
| Control       | -1.421E-14±1.53c                      | 0.00±10.75c                          |
| Citronella oil| 100.00±0.88a                         | 85.56±6.21ab                        |
| Cinnamon oil  | 80.67±0.88b                          | 70.56±6.21b                         |
| Tung oil      | B                                     | 91.67±6.21ab                        |
| Gamal oil     | B                                     | 97.78±6.21a                         |
| Ramayana oil  | B                                     | 88.33±6.21ab                        |
| Dish soap     | 99.00±0.88a                          | -                                     |
| Deltamethrin  | 100.00±0.88a                         | 98.89±6.21a                         |

a Mortality percentage in the same column followed by the same letter is not significantly different based on Duncan test at α=5%.

b Not tested on that method.

Based on concentration levels, concentration levels of 3% and 5% of all plants oil have the same effect as deltamethrin (on concentration levels 0.05%, 0.075%, and 0.1%) against mealybugs mortality in both methods of KS (F(4,52)=1033.61, p<0.05)) and BS (F(4,32)=2039.17, p<0.05) (Table 3). The average of mealybugs mortality was 100% at 7 DAT for all types of plants oil.

Table 3 Mortality average of Planococcus sp. based on differences in concentration levels.

| Level of concentration (%) | Mortality average at 7 DAT (%)± Std. Error a |
|----------------------------|----------------------------------------------|
|                            | KS b                                         | BS b                                    |
| 0                          | -1.421E-14±1.53c                             | 0.00±7.21c                             |
| 0.05                       | 100.00±0.53a                                 | 96.67±7.21a                            |
| 0.075                      | 100.00±0.53a                                 | 100.00±7.21a                           |
| 0.1                        | 100.00±0.53a                                 | 100.00±7.21a                           |
| 1                          | 79.67±0.88b                                  | 68.33±3.23b                            |
| 3                          | 100.00±0.88a                                 | 92.00±3.23a                            |
| 5                          | 100.00±0.88a                                 | 100.00±3.23a                           |
Mortality average in the same column followed by the same letter is not significantly different based on Duncan test at α=5%.

Spraying on mealybugs directly.

Spraying cacao pods.

In addition, there is also a significant interaction between oil type and concentration level to mortality percentage in the KS method ($F_{(4,52)}=1777.22$, $p<0.005$). Only the control and the cinnamon leaves oil 1% had different interactions where the mortality average of Planococcus sp. is less than 50% at 7 DAT (Table 4). In the BS method, the interaction between oil type and concentration level to mortality percentage showed no significant difference ($F_{(4,38)}=406.11$, $p>0.005$).

**Table 4** Mortality average of Planococcus sp. based on the interaction between oil and concentration level on the spraying on mealybugs directly (KS) method at 7 DAT.

| Treatment       | Concentration (%) | Mortality average (%)± Std. Error ± |
|-----------------|-------------------|-------------------------------------|
| Control         | 0                 | -1.421E-14± 1.53c                   |
| Citronella oil  | 1                 | 100± 1.53a                          |
| Citronella oil  | 3                 | 100± 1.53a                          |
| Citronella oil  | 5                 | 100± 1.53a                          |
| Cinnamon oil    | 1                 | 42± 1.53b                           |
| Cinnamon oil    | 3                 | 100± 1.53a                          |
| Cinnamon oil    | 5                 | 100± 1.53a                          |
| Dish soap       | 1                 | 97± 1.53a                           |
| Dish soap       | 3                 | 100± 1.53a                          |
| Dish soap       | 5                 | 100± 1.53a                          |
| Deltamethrin    | 0.05              | 100± 1.53a                          |
| Deltamethrin    | 0.075             | 100± 1.53a                          |
| Deltamethrin    | 0.1               | 100± 1.53a                          |

*Mortality average in the same column followed by the same letter is not significantly different based on Duncan test at α=5%.

3.3. Value of $LC_{50}$ and $LT_{50}$

Table 5 performed the estimation of plant oil toxicity parameters to Planococcus sp. death on 3, 5, and 7 DAT. In general, the concentration level needed will be higher to kill mealybugs faster. Citronella oil could kill 50% of the population of Planococcus sp. at the lowest concentration among all types of oil tested. At 3DAT, the value $LC_{50}$ MSW is 0.70 (0.00-0.63)% in the KS method, while in BS the value of $LC_{50}$ MSW is 1.54 (1.41-1.68)% All mealybugs were dead at 5 DAT. Citronella oil has been known to be insecticidal in some pests. Citronellal compounds can act as a contact, stomach poison, or repellent. MDG, MDR, and MBKS can also potentially be stomach poison. Those oil can kill 50% of the mealybugs population at a concentration level less than 1% in the BS method at 7 DAT ($LC_{50}$ MDG = 0.55%, $LC_{50}$ MDR = 0.92%, $LC_{50}$ MBKS = 0.86%). Gamal and ramayana plants are easily found in cacao plantations because they were planted as shade plants. So that farmers can use them as a material controlling Planococcus in their plantation.
Table 5 Estimation of plants oil toxicity parameters to *Planococcus* sp. mortality at 3, 5, and 7 DAT.

| Perlakuan | Parameter | Observation Time |
|-----------|-----------|------------------|
|           |           | 3 DAT<sup>b</sup> | 5 DAT<sup>b</sup> | 7 DAT<sup>b</sup> |
| **MSW**<sup>c</sup> | KS<sup>d</sup> | Slope | 2.23±0.39 | 1.95±0.27 | 0.70(0.00-0.63) |
|           |           | Intercept | 1.95±0.27 | h | h |
|           |           | LC<sub>50</sub> (%)<sup>f</sup> | 0.70(0.00-0.63) | | |
|           | BS<sup>e</sup> | Slope | 7.23±0.81 | 4.34±0.63 | 2.58±0.66 |
|           |           | Intercept | -1.36±0.22 | -0.34±0.16 | 0.53±0.17 |
|           |           | LC<sub>50</sub> (%)<sup>f</sup> | 1.54 (1.41-1.68) | 1.20 (0.68-1.56) | 0.62 (0.00) |
| **MDKM**<sup>c</sup> | KS<sup>d</sup> | Slope | 1.77±0.70 | 4.64±1.31 | 9.158±12.93 |
|           |           | Intercept | -0.91±0.66 | -1.97±0.80 | -0.24±0.15 |
|           |           | LC<sub>50</sub> (%)<sup>f</sup> | 3.25 (0.12-5.46) | 2.65 (1.53-3.21) | 1.06 (0.00) |
|           | BS<sup>e</sup> | Slope | 8.50±1.14 | 5.53±0.66 | 4.78±0.65 |
|           |           | Intercept | -2.55±0.39 | -1.17±0.19 | -0.46-0.16 |
|           |           | LC<sub>50</sub> (%)<sup>f</sup> | 1.99 (1.45-2.50) | 1.63 (1.13-2.17) | 1.25 (0.70-1.66) |
| **MBKS**<sup>c</sup> | KS<sup>d</sup> | Slope | 12.24±1.58 | 3.18±0.53 | 10.06±10.87 |
|           |           | Intercept | -4.29±0.56 | -0.61±0.16 | 0.67±0.18 |
|           |           | LC<sub>50</sub> (%)<sup>f</sup> | 2.24 (0.00) | 1.56 (0.00) | 0.86 (0.00) |
| **MDG**<sup>c</sup> | KS<sup>d</sup> | Slope | 6.55±0.75 | 5.07±0.78 | 5.86±5.28 |
|           |           | Intercept | -1.48±0.23 | -0.11±0.16 | 1.50±0.25 |
|           |           | LC<sub>50</sub> (%)<sup>f</sup> | 1.68 (1.54-1.83) | 1.05 (0.89-1.18) | 0.55 (0.00) |
| **MDR**<sup>c</sup> | BS<sup>e</sup> | Slope | 5.86±5.28 | 3.89±0.60 | 10.72±9.32 |
|           |           | Intercept | 1.50±0.25 | -0.17±0.16 | 0.39±0.17 |
|           |           | LC<sub>50</sub> (%)<sup>f</sup> | 2.13 (1.77-2.55) | 1.10 (0.90-1.27) | 0.92 (0.00) |
| **SCP**<sup>c</sup> | KS<sup>d</sup> | Slope | 2.47±0.30 | 5.15±11.00 | 4.72±11.63 |
|           |           | Intercept | -0.36±0.13 | 1.67±0.21 | 1.88±0.25 |
|           |           | LC<sub>50</sub> (%)<sup>f</sup> | 1.39 (0.73-1.97) | 0.48 (0.00) | 0.40 (0.00) |
| **BS**<sup>e</sup> | Slope | 1.36±0.71 | 5.50±7.406 | 5.50±7.41 |
|           | Intercept | 1.04±0.20 | 1.83±0.31 | 1.83±0.31 |
|           | LC<sub>50</sub> (%)<sup>f</sup> | 0.17 (0.00) | 0.47 (0.00) | 0.47 (0.00) |

<sup>a</sup>Methods
<sup>b</sup>Days After Treatment
<sup>c</sup>MSW (citronella oil), MDKM (cinnamon leaves oil), MKS (tung oil), MDG (gamal leaves oil), MDR (ramayana leaves oil), SCP (dish soap).
<sup>d</sup>Spraying on mealybugs directly method.
<sup>e</sup>Spraying on cacao pods method.
<sup>f</sup>Confident Limit 95%
<sup>g</sup>Not tested on this method.
<sup>h</sup>No statistics are computed because the ratios of response counts to subject counts are the same, i.e. the slope is zero.

Based on LT<sub>50</sub> values, the higher the concentration of plant oils, the faster the death of mealybugs. For example, MSW killed *Planococcus* sp. faster than any other type of oil in either the KS or BS methods (Table 6). In the KS method, MSW killed 50% of the mealybugs populations in less than two
days, and the fastest time is at MSW 5% (LT$_{50}$=1.36 (1.24-1.47) days). Similarly, in the BS method, MSW 5% could kill Planococcus in less than 8 hours (LT$_{50}$ =0.33 days). Therefore, it means that MSW in BS are more effective than KS. Oil residues on the pods obtained mealybugs exposed longer and into its digestion.

However, in the BS method, the smallest LT$_{50}$ value is at the MBKS 5% (LT$_{50}$=0.24 (0.00-0.56) days) (Table 6). In addition, tung oil being used as a biofuel and has insecticidal activity because it contains alpha eleostearic acid, a stomach poison. This oil can control trunk borer pests in nutmeg, pepper, and cloves. In the BS method, MDG 5% and MDR 5% are also able to kill mealybugs in less than 1day (LT$_{50}$ MDG 5% =0.58 (0.27-0.79) days and LT$_{50}$ MDR 5%=0.67 (0.36-0.96) days). Although in the KS method, these two types of oil only can kill less than 70% at the time of initial screening (Table 1, Figure 1). So sublethal concentration testing has not been conducted. In MDKM 5%, it is more effective if applied with BS (LT$_{50}$ =0.43 (0.04-0.68) days). If the level of MDKM concentration is less or equal to 1%, the time of death will be longer, which is more than 8 days (LT$_{50}$ MDKM 1% (KS)= 8.59 (7.16-11.34) days), LT$_{50}$ MDKM 1% (BS)=10.10 (7.21-30.37) days).

Table 6 LT$_{50}$ value of plants oils against Planococcus sp. mortality at 7 DAT.

| Treatment | K$^a$ | Mortality average at 7 HSP (%)± Std. Error | BS$^b$ | LT$_{50}$ (day)$^c$ |
|-----------|-------|------------------------------------------|-------|---------------------|
|           | Slope | Intercept | LT$_{50}$ (day)$^e$ | Slope | Intercept | LT$_{50}$ (day)$^e$ |
| MSW$^b$   | 1     | 7.54±0.63 | 1.80±0.205 | 1.74 (1.62-1.84) | 4.44±0.48 | -3.17±0.33 | 5.17 (4.49-6.17) |
| 3         | 4.46±0.35 | -0.68-0.12 | 1.42 (1.22-1.61) | 3.73±0.34 | -1.82±0.21 | 3.07 (2.50-3.60) |
| 5         | 4.99±0.41 | -0.66±0.13 | 1.36 (1.24-1.47) | 4.31±5.98 | 2.09±0.39 | 0.327 (0.00) |
| MDKM$^b$  | 1     | 1.99±0.25 | -1.86±0.17 | 8.59 (7.16-11.34) | 2.57±0.46 | -2.58±0.32 | 10.10 (7.21-30.37) |
| 3         | 3.48±0.24 | -1.53±0.14 | 2.76 (2.46-3.04) | 3.30±0.34 | -2.00±0.22 | 10.10 (7.21-30.37) |
| 5         | 5.01±0.34 | -1.94±0.18 | 2.44 (2.21-2.66) | 3.41±1.19 | 1.26±0.22 | 0.426 (0.04-0.68) |
| MBKS$^b$  | 1     | g | g | g | 7.02±0.76 | -5.16±0.55 | 5.43 (4.97-6.03) |
| 3         | g | g | g | 2.59±1.13 | 1.601±0.26 | 5.43 (4.97-6.03) |
| 5         | g | g | g | 2.59±1.13 | 1.601±0.26 | 0.24 (0.00-0.56) |
| MDG$^b$   | 1     | g | g | g | 6.20±0.62 | -4.32±0.43 | 4.98 (4.58-5.45) |
| 3         | g | g | g | 6.20±0.62 | -4.32±0.43 | 4.98 (4.58-5.45) |
| 5         | g | g | g | 3.75±0.94 | 0.879±0.18 | 0.58 (0.27-0.79) |
| MDR$^b$   | 1     | g | g | g | 5.31±0.61 | -4.08±0.44 | 5.87 (5.21-7.01) |
| 3         | g | g | g | 5.48±0.45 | -2.72±0.26 | 3.14 (2.54-3.74) |
| 5         | g | g | g | 1.93±0.30 | 0.33±0.15 | 0.67 (0.36-0.96) |
| SCP$^b$   | 1     | 7.47±0.72 | -3.90±0.46 | 3.33±2.37-3.93 | g | g | g |
| 3         | 9.33±2.13 | -3.93±1.16 | 2.64±0.00 | g | g | g |
| 5         | 13.25±10.83 | -5.16±5.12 | 2.45±0.00 | g | g | g |
| Delta     | 0.05  | 6.12±0.78 | -0.03±0.13 | 1.02 (0.85-1.14) | 2.53±0.31 | -0.02±0.14 | 1.02 (0.59-1.37) |
| 0.075     | 2.66±0.82 | 1.51±0.19 | 0.27 (0.02-0.51) | 3.26±0.40 | -0.02±0.15 | 1.01 (0.79-1.21) |
| 0.1       | g | g | g | 3.3±0.72 | 0.78±0.18 | 0.58 (0.30-0.79) |

$^a$ Concentration.
$^b$ MSW (citronella oil), MDKM (cinnamon leaves oil), MKS (tung oil), MDG (gamal leaves oil), MDR (ramayana leaves oil), SCP (dish soap), Delta (deltamethrin)
$^c$ Standard Error
$^d$ Spraying on mealybugs directly method.
$^e$ Spraying on cacao pods method.
$^f$ Confident Limit 95%
$^g$ c$^h$ or tested on this method
$^h$ No statistics are computed because the ratios of response counts to subject counts are the same, i.e. the slope is zero.
4. Conclusion
All types of oils at a concentration of 5% in the KS and BS methods can kill mealybugs equivalent to deltamethrin. The smallest value of LC$_{50}$ 3 DAT is at the MSW (KS) (LC$_{50}$=0.70(0.00-0.63)%), while at 7 DAT, all test insects on MSW treatment have died, and the next lowest LC$_{50}$ value is in MDG (BS) (LC$_{50}$=0.55 (0.00)%). The fastest time for LT$_{50}$ on the KS methods is at MSW 5% (LT$_{50}$=1.35 (1.24-1.47) days, while in the BS method is at MBKS 5% (LT$_{50}$ =0.24 (0.00-0.56) days.

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