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# The management practice methods for *Allocarsidara malayensis* (Crawford) by spraying insecticide with AI drone and long hose pump sprayers in durian orchards

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**Abstract** The population density of *Allocarsidara malayensis* (Crawford) on the young leaves of 3-year-old 'Kradum Thong' durian trees was significantly lower at 3 and 30 days after applying the cypermethrin insecticide solution using AI drone sprayers (specifically the EA-30X model artificial intelligence drones). Additionally, there was less insect damage and fewer infestation symptoms compared to the long hose pump sprayer. Both AI $drone_{Nor}$ and AI $drone_{Hi}$ sprayers used a chemical insecticide amount of 0.273-0.545 L/ha, with water consumption ranging between 272.5-272.8 L/ha. These amounts were significantly lower ($P \leq 0.01$) than those of the long hose pump sprayer (1.237 L/ha with water consumption of 1,237 L/ha). These results confirm that both AI $drone_{Hi}$ and AI $drone_{Nor}$ sprayers effectively delivered the insecticide to healthy plants. The infested young leaves exhibited rapid recovery when treated with the cypermethrin insecticide. Moreover, cypermethrin did not cause any phytotoxic symptoms in the durian trees. Both AI drone sprayers significantly reduced insecticide solution application without any loss of solution, and their time consumption was also significantly lower compared to the long hose pump sprayer. Additionally, both AI drone sprayers incurred lower expenses in terms of labor, insecticide usage, water consumption, and electricity compared to the long hose pump sprayer. The AI drone sprayers demonstrated a lower gross cost for insecticide spraying and higher work efficiency. Therefore, using AI drone sprayers to apply cypermethrin insecticide solution has proven effective and efficient for controlling durian psyllids such as *Allocarsidara malayensis* (Crawford). Regularly applying the chemical insecticide solution containing cypermethrin to young leaves at 15-day intervals using AI drone sprayers is crucial to ensure the overall health of durian trees and minimize infestation by *Allocarsidara malayensis* (Crawford).

**Keywords:** Artificial intelligence, Drone, Durian, Efficiency, Insecticide, Psyllid

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## Introduction

Durian (*Durio zibethinus* Murr.) is one of the most popular and desirable tropical fruits in Southeast Asian nations due to its high value in nutrition (Striegel *et al*., 2018), and unique taste, which is highly appreciated by consumers throughout Asia (Wiangsamut and Wiangsamut, 2023). One of the most popular durian cultivars that are preferred by both local and global consumers is 'Kradum Thong' attributed to its distinct characteristics— its relatively small fruit size (weighing approximately 1 kg) and its fruit boasts a delicate, soft, and light yellow flesh; althought the flesh is relatively thin, it possesses a mild aroma and a delightful sweet taste, not oily in texture unlike other durian cultivars (Sigvanich, 2022), and it contained a considerable amount of dietary fibre (7.5-9.1 g/100 g dry matter) and high amounts of carbohydrate and sugar (62.9-70.7 g and 47.9-56.4 g/100 g dry matter, respectively (Charoenkiatkul *et al*., 2016). Among the various cultivated durian regions in Thailand, the 'Monthong' variety comprises the largest share at 41%, followed by 'Chanee' at 33%, 'Gan Yao' and 'Kradum Thong' make up 5% and 2%, respectively, while the remaining portion is occupied by minor cultivars (Bangkok Post, 2018). Thailand holds the distinction of being the largest global exporter of the renowned durian fruit, commanding an impressive 93.3% share of the international market (Abhasakun, 2023), due to a notable expansion in the cultivation of durian in Thailand, with a total plantation area of 168,778 hectares (ha), which represents a growth of 12,768 ha (8.18%) compared with the previous year (OAE, 2023). The Office of Agricultural Economics (2023) has released a recent report stating that the average fruit yield reached 233.12 kg/ha, indicating a significant growth of 6.58% (14.4 kg/ha) in comparison to the yield observed in 2022. Insect pests have been widely recognized for their ability to inflict catastrophic consequences and significantly diminish global food grain production. According to the Food and Agriculture Organization (FAO), the projected losses resulting from pests and diseases are estimated to exceed 37% (Subramanian *et al*., 2021).

Although the cultivation of durian has witnessed substantial expansion, it has also encountered detrimental effects from a range of insects and pests. Notably, the durian psyllids [*Allocarsidara malayensis* (Crawford)], which are plant sap-sucking insects, pose a significant threat to the young leaves of durian trees (Anutrakunchai *et al*., 2023). The biotic disturbance, known as the period of durian psyllids outbreak, occurs in Thailand from June to November. During this time, there is a continuous increase in the population of insects in response to the warmer climate. Adult females lay eggs that go through approximately five instars (nymphal growth stages) before reaching maturity as winged adults.

Psyllids proliferate during the spring season, coinciding with the rise in temperatures and the emergence of fresh growth flushes from their host plants (Kabashima *et al*., 2014). According to the report by the Ministry of Agriculture and Cooperatives (2023), it was found that the durian psyllid exclusively caused damage to the young leaves that were still in the process of growing. Due to biotic disturbance, the photosynthetic rate per unit leaf area was notably diminished by 34.8%. Biotic disturbance had a significant impact on various parameters related to the photosynthetic rate per unit leaf area, such as photosynthetic pigments (e.g., a+b, a, and b), as well as chlorophyll fluorescence properties. In addition to diseases, the type of disturbance caused by insects emerged as the second most influential factor influencing the response of the photosynthetic rate per unit leaf area (Zhang *et al*., 2022). The impact of this phenomenon can have a significant influence on the production of durians and the financial losses incurred by the agricultural sectors, especially in developing nations such as Thailand. Therefore, it is crucial to apply insecticides to the durian trees during the initial growth phase of their leaves, when they are susceptible to infestation by durian psyllids. The conventional method of utilizing long hose pump sprayers by farmers to apply insecticide (cypermethrin) results in significant consumption of energy, time, and labor resources. Foreign labor has played a crucial role in supporting agricultural management practices. However, the scarcity of labor has become a significant challenge for durian production in Thailand. In order to tackle this issue, the implementation of unmanned aerial vehicles (UAVs) equipped with EA-30X model artificial intelligence (AI) drones for insecticide spray applications has not yet been explored in durian plantations. The objective was to evaluate the effectiveness of *Allocarsidara malayensis* (Crawford) management practices by comparing insecticide (cypermethrin) spraying methods using AI drones and traditional long hose pump sprayers in durian orchards.

## Materials and methods

### *Place and period of study, climate condition, and outbreak of the Allocarsidara malayensis* (Crawford)

The experiment was conducted in a durian orchard located at Rajamangala University of Technology Tawan-Ok at Chanthaburi Campus, Chanthaburi, Thailand. The orchard consisted of three-year-old trees of the ‘Kradum Thong’ cultivar. The orchard's geographical location was determined by its coordinates of 12.82853 latitude (12°49'42.72204"N) and 102.10665 longitude (102°6'23.9418"E), while its elevation stood at 49 meters above sea level. Throughout the experimental period, spanning from October 2022 to December 2022, the precipitation levels exhibited fluctuations, ranging from high to low. The recorded values for October, November, and December 2022 were 380.5 mm, 186.5 mm, and 27.3 mm, respectively. The relative humidity varied between 72.5% and 89.8%. Throughout the day, the temperature ranged from 33.5 °C to 37.7 °C, while during the night, it ranged from 15.7 °C to 24.4 °C. Additionally, the rate of water evaporation during this period was observed to be between 3.9-4.7 mm/day. The soil was classified as a sandy loam type according to the OARDR (2015) report. It exhibited a pH value of 4.73, an electrical conductivity of 0.03 mS/cm, an organic matter content of 2.36%, a phosphorus level of 20.99 mg P/kg, a potassium level of 22.98 mg K/kg, a calcium level of 84.14 mg Ca/kg, and a magnesium level of 16.98 mg Mg/kg (OARDR, 2023). On October 15, 2022, the outbreak of durian psyllids [*Allocarsidara malayensis* (Crawford)] was observed on the young leaves of durian trees. Subsequently, an experimental layout was conducted to tackle this problem at the new leaf growth stages.

### *Experimental design and selection of durian trees infested with Allocarsidara malayensis* (Crawford)

The experiment was conducted using a completely randomized design (CRD). There were three treatments, each representing a different type of sprayer: 1) Long hose pump$_{Nor}$ sprayer for chemical insecticide solution at the concentration of 1 ml/L, served as the control (controlled treatment); 2) AI Drone$_{Nor}$, or artificial intelligence (AI) drone sprayer (EA-30X model) for chemical insecticide solution at the concentration of 1 ml/L [or 1 millimeter (ml) per 1 liter (L) of clean water] and; 3) AI Drone$_{Hi}$, or AI drone sprayer (EA-30X model) for chemical insecticide solution at the concentration of 2 ml/L. It is important to note that cypermethrin 35% W/V EC was used in all treatments and this cypermethrin [(*RS*)-α-cyano-3-phenoxybenzyl (1*RS*,3*RS*;1*RS*,3*SR*)-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropane carboxylate] is a highly active synthetic pyrethroid insecticide. Twenty durian trees of the 'Kradum Thong' cultivar, which were naturally and completely infested with *Allocarsidara malayensis* (Crawford), were selected for this study. The trees were selected by similar tree height size, close canopy diameter, and identical tree health status. Each treatment was replicated five (5) times, with one durian tree per replication, in a total of 20 trees (3-year-old tree of durian cv. 'Kradum Thong', one tree per planting hole with tree spacing of 8 m x 8 m, 156 trees/ha). Tree height varied between 3.0 to 4.9 m, while the tree canopy ranged from 2.06 to

3.71 m. In each treatment, the cypermethrin insecticide solution was sprayed twice, with the initial application taking place on October 25, 2022, and the second on November 9, 2022. The time interval between the two applications was 15 days, and the spraying was conducted at 0700H for all 20 trees.

Twenty durian trees of the 'Kradum Thong' cultivar were sprayed by both the skid pump (long hose pump) sprayer and AI drone sprayers for chemical insecticide solution (Figures 1a-1c). The long hose pump sprayer, equipped with a 5.5-horsepower, was utilized for the long hose pump application. It had a 3-cylinder pump with a 1-inch suction cup and a 50-m long hose with a diameter of 3/8 inch (Figure 1b). The spraying pressure could go as high as 560 pound-force per square inch (psi), ensuring efficient distribution and coverage across the canopy. This setup allowed the precise delivery of a insecticide to the target durian trees. The efficiency of the EA-30X model, an AI drone, was tested using a cruise speed of 0.5 m/s and a flight height of 2.7 m above the tip of the tree canopy (Figure 1c). In order to optimizer the drone's spraying efficiency, a single spray passage was installed for each row, spanning a width of 5 m. It utilized centrifugal mist spray nozzles with two active nozzles, resulting in better canopy deposition and coverage.


**Figure 1.** (a) A three-year-old durian tree; spraying of the cypermethrin insecticide solution by (b) long hose pump sprayer and (c) AI drone sprayer on three-year-old durian trees

### *Plant measurement and data gathered*

The tree parameters were measured: using a measuring tape attached to the stem of the tree from the base of the stem on the ground to the tip of the tree in meters (m) for tree height, and from one edge of the leaf canopy to the opposite through the stem's center of the tree in meters (m) for canopy diameter (Wiangsamut and Wiangsamut, 2022). Chemical insecticide use refers to the total quantity of chemical insecticide dissolved in clean water and sprayed on durian trees to eliminate the durian psyllids [*Allocarsidara malayensis* (Crawford)] in a one-hectare area, which is expressed in liters per hectare (L/ha). Water consumption refers to the amount of clean water used to dilute chemical insecticides for spraying on durian trees affected by *Allocarsidara malayensis* (Crawford) in a one-hectare area, which is measured in units of L/ha. Insecticide solution application refers to the amount of chemical insecticide mixed with clean water; this mixture is then used to kill *Allocarsidara malayensis* (Crawford) on durian trees in a one-hectare area, which is measured in L/ha. Insecticide solution loss refers to the amount of insecticide solution that falls on the ground after spraying it on durian trees infested with *Allocarsidara malayensis* (Crawford) in a one-hectare area basis, which is measured in L/ha. The amount of insecticide solution loss was collected using transparent plastic sheets on the ground in durian fields. Percentage of insecticide solution loss is computed by multiplying the amount of insecticide solution loss by 100 and divided by the amount of insecticide solution applied. Time consumption refers to the duration it takes for sprayers to complete the task of spraying insecticide solution on durian trees infested with *Allocarsidara malayensis* (Crawford) in a one-hectare area, which is measured in hours per hectare (h/ha). Population density of *Allocarsidara malayensis* (Crawford) was evaluated on October 15, 2020, which took place during the stage of young leaf growth before applying or spraying the insecticide solution. Subsequently, the evaluation of this parameter took place at intervals of 3, 30, and 60 days following the first application of spray. Insect population counting is conducted by observing the number of insects found at positions marked at 3 points per branch of the durian tree. The observation focused on the presence of *Allocarsidara malayensis* (Crawford) at the designated positions. Population levels are categorized as follows: 1-3 insects found = 1-25%, 4-6 insects found = 26-75%, and 7-10 insects found = 76-100%. The damage level to plant infestation by *Allocarsidara malayensis* (Crawford) was categorized into 5 levels as follows: 0 = no damage or 0%, 1 = young durian leaves that had small-sized lesions covering 1-25% of the leaf area, 2 = young durian leaves that had lesions covering 26-50% of the leaf area, 3 = young durian leaves that had lesions covering the entire leaf, with the presence of sooty mold covering 51-75%, and 4 = young durian leaves that were distorted, wilted, and fallen, 76-100%. The cost of chemical insecticide solution spraying to control *Allocarsidara malayensis* (Crawford) using an AI drone and long hose pump were calculated based on the cost of two rounds of spraying, with a 15-day interval, which was recorded in US dollars per hectare (USD/ha).

***Data analysis***

The data analysis was performed using the software Statistix 10 (SXW). To compare the means of four treatments and identify any significant differences, a one-way analysis of variance (ANOVA) was conducted. The means were compared using the Least Significant Difference (LSD) test at a 0.01 probability level.

## Results

***Infestation characteristics of durian psyllids on young leaves***

At a period of 10 days before the application of spray, signs of infestation caused by durian psyllids [*Allocarsidara malayensis* (Crawford)] were observed on every young leaf of the durian plant. However, these pests were not detected on the mature leaves, which exhibit a dark green coloration (Figure 2a).

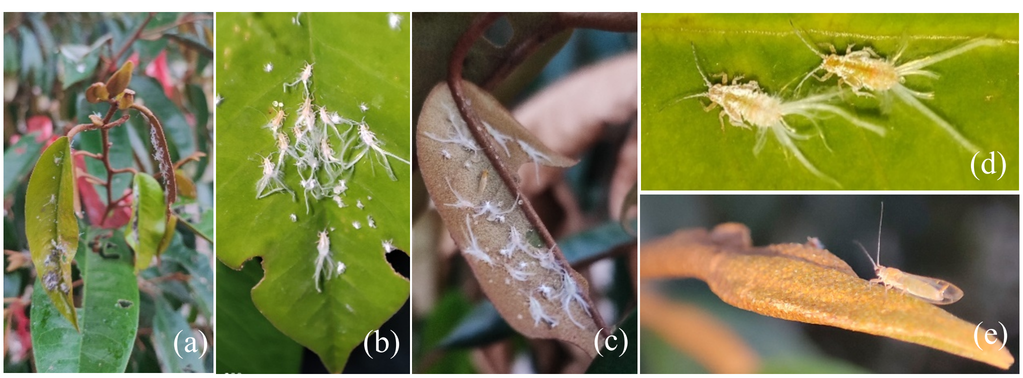


**Figure 2.** Infestation characteristics of *Allocarsidara malayensis* (Crawford) on young leaves of durian (a); third instar nymph on the adaxis of a leaf (b); fourth instar nymph on the abaxis of a leaf (c); fifth instar nymph that shaped like a miniature bantam chicken and (d); adult stage of durian psyllids (e)

The third instar nymphs were discovered to infest the adaxis of a leaf (Figure 2b), whereas the fourth instar nymphs infested the abaxis of a leaf (Figure 2c). The fifth instar nymph, when enlarged resembles a bantam chicken, was discovered on both adaxis and abaxis of young leaves (Figure 2d). When durian psyllids had reached the adult stage, they exclusively infested the young leaves of durian (Figure 2e). All nymphal growth stages and adult durian psyllids can infest durian trees by sucking the sap from young durian leaves.

***Population density of Allocarsidara malayensis* (Crawford)**

The population density of *Allocarsidara malayensis* (Crawford), commonly known as durian psyllid, was evaluated on the young leaves of durian 10 days prior to the application of any spraying. The evaluation revealed a consistent population density of 100% across all the leaves, with no significant difference observed. This finding suggests a severe infestation of durian psyllids on the trees (Data not shown). However, the population density of durian psyllids was significantly reduced ($P \leq 0.01$) at 3 and 30 days after the application of the insecticide solution (or days after spraying: DAS) using both AI drone$_{Hi}$ and AI drone$_{Nor}$ sprayers (Figure 3). Additionally, there was a significant decrease in insect damage and fewer signs of infestation on young durian leaves compared to the utilization of a long hose pump sprayer. These findings exhibited statistical significance ($P \leq 0.01$) (Figures 3, 4, and 5). In contrast, the level of insect damage escalated to 100% for all three types of sprayers (AI drone$_{Hi}$, AI drone$_{Nor}$, and long hose pump) at 60 DAS (Figure 4). In both AI drone$_{Hi}$ and AI drone$_{Nor}$ treatments, it was observed that *Clethrogyna turbata* (Butler), *Hypomeces squamosus* (Fabricius), *Thosea* (Walker), and *Hyalarcta huebneri* (Westwood), which are insects and pests, were simultaneously causing damage to young durian leaves at 60 DAS (Figure 6).

The result indicated that the range of tree height of a 3-year-old durian cv. ‘Kradum Thong’, which was between 3.52 to 4.26 m, and the range of tree height did not vary significantly ($P > 0.01$) (Table 1). Its canopy diameter varied from 2.57 to 3.15 m and there were no significant differences observed between these values ($P > 0.01$). The application of AI drone$_{Nor}$ and AI drone$_{Hi}$ sprayers resulted in a statistically significant reduction in the amount of chemical insecticide use ($P \leq 0.01$), particularly in the case of AI drone$_{Nor}$ when compared to the control (long hose pump sprayer). Additionally, both AI drone sprayers required lower volume of water consumption ($P \leq 0.01$) for diluting the chemical insecticide compared to the control.

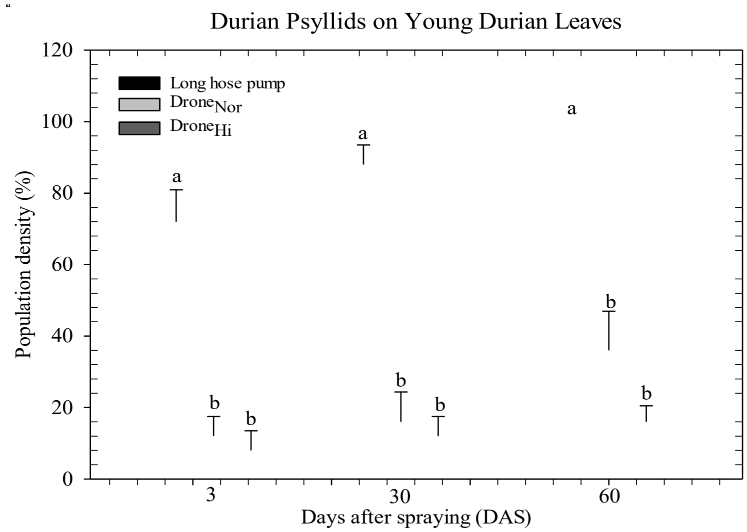


**Figure 3.** Population density of *Allocarsidara malayensis* (Crawford) on durian tree after spraying the insecticide solution by long hose pump, AI drone$_{Hi}$, AI drone$_{Nor}$ sprayers at 3, 30, and 60 days; In each day after spraying (DAS), treatments followed by the same letter did not differ by Least Significant Difference (LSD) at a 0.01 probability level

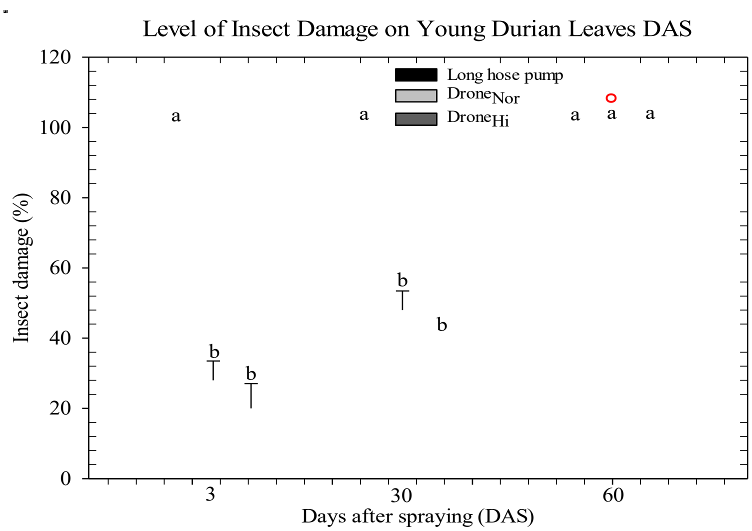


**Figure 4.** Level of insect damage by *Allocarsidara malayensis* (Crawford) on durian leaves after spraying the insecticide solution at 3, 30, and 60 days by long hose pump, AI drone$_{Hi}$, AI drone$_{Nor}$ sprayers; In each day after spraying (DAS), treatments followed by the same letter did not differ by the least significant difference (LSD) at a 0.01 probability level; ∘, insects and pests that simultaneously causing damage to young durian leaves at 60 DAS

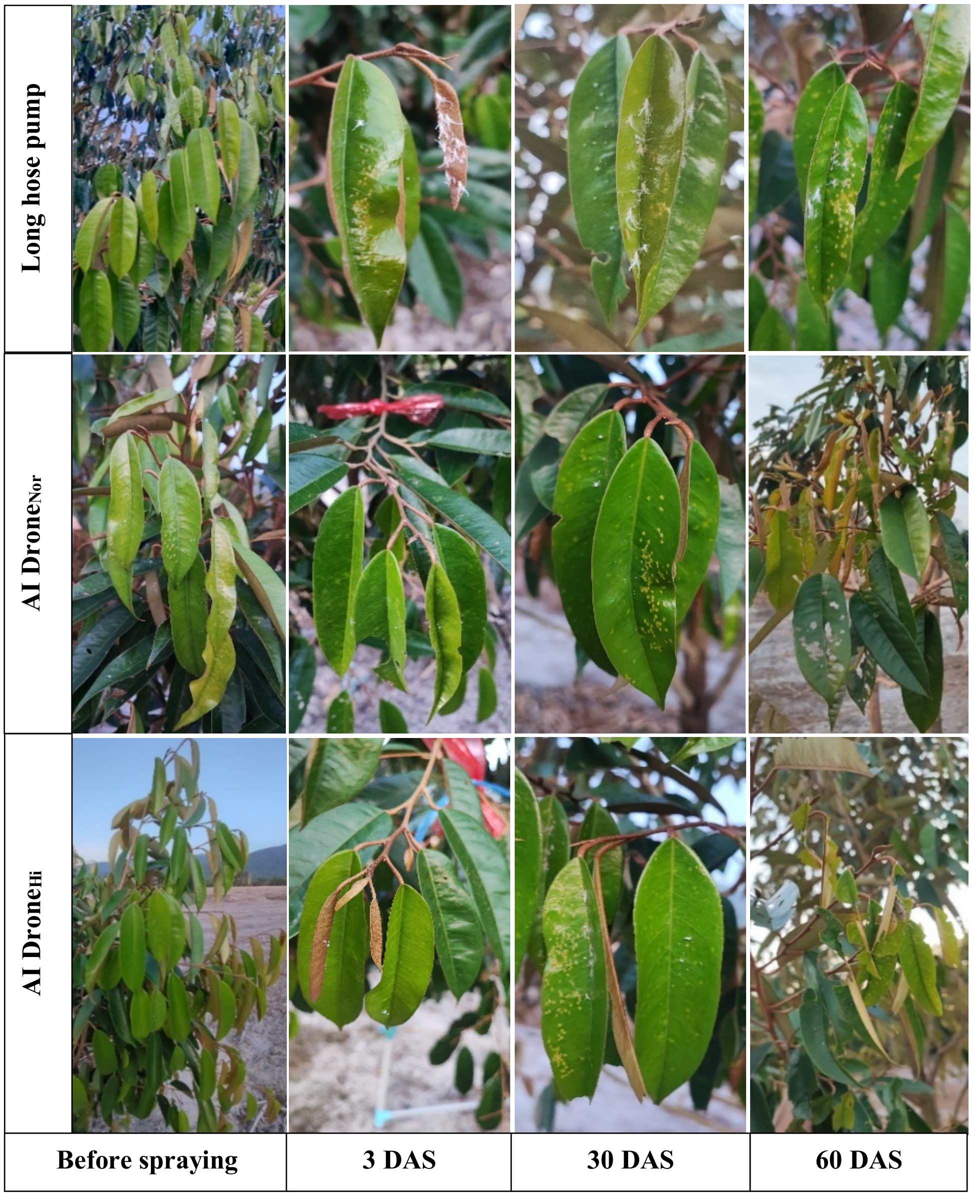


**Figure 5.** Infestation symptoms of *Allocarsidara malayensis* (Crawford) on durian trees before spraying the insecticide solution by long hose pump, AI drone$_{Hi}$, AI drone$_{Nor}$ sprayers and after spraying at 3, 30, and 60 days (DAS)

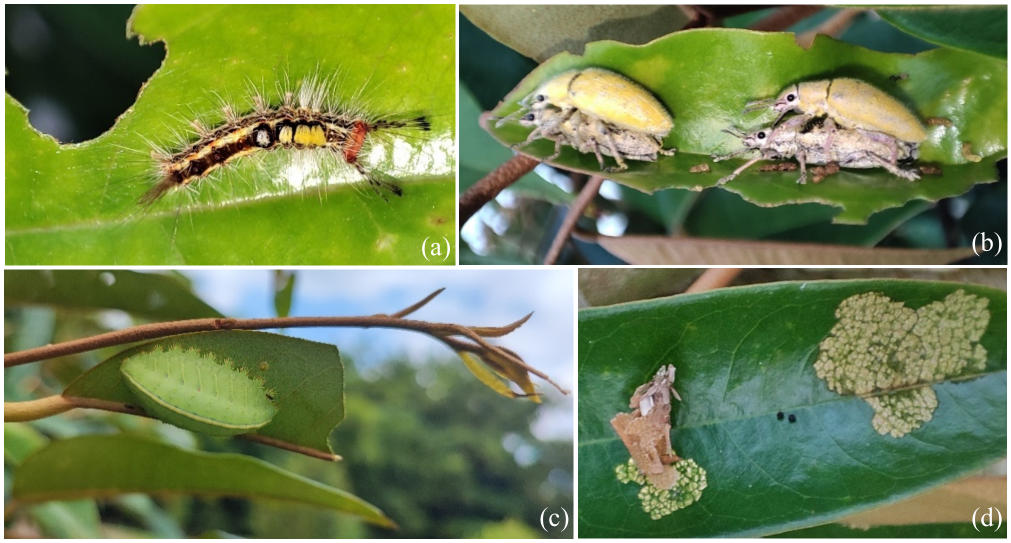


**Figure 6.** Insects and pest were found destroying concurrently on young durian leaves: (a)*Clethrogyna turbata* (Butler); (b) *Hypomeces squamosus* (Fabricius); (c) *Thosea* (Walker) and; (d) *Hyalarcta huebneri* (Westwood)

**Table 1**. Tree height, canopy diameter, chemical insecticide use, and water consumption that were used in the experiment

| Type of sprayer | Tree height (m)/1 | Canopy diameter (m)/1 | Chemical insecticide use (L/ha)/1 | Water consumption (L/ha)/1 |
|---|---|---|---|---|
| Long hose pump (control) | 4.26$^{a}$ | 3.15$^{a}$ | 1.237$^{a}$ | 1,237.0$^{a}$ |
| AI drone$_{Nor}$ | 3.82$^{a}$ | 2.57$^{a}$ | 0.273$^{c}$ | 272.8$^{b}$ |
| AI drone$_{Hi}$ | 3.52$^{a}$ | 2.58$^{a}$ | 0.545$^{b}$ | 272.5$^{b}$ |
| F-test (0.01) | ns | ns | ** | ** |
| CV(%) | 11.78 | 15.84 | 0.35 | 0.32 |

1/ in treatment column, means with the same letter is not significantly different; CV, coefficient of variation; ns, non-significant difference at 0.01 probability level ($P > 0.01$) through Least Significant Difference (LSD)

***Insecticide solution application, Insecticide solution loss, percentage of Insecticide solution loss, and time consumption as sprayed by various types of sprayers on 3-year-old durian trees cv. 'Kradum Thong'***

Both AI drone$_{Nor}$ and AI drone$_{Hi}$ sprayers had significantly lower insecticide solution application ($P \leq 0.01$) with no loss of solution ($P \leq 0.01$), and very significantly lower time consumption ($P \leq 0.01$) compared to the long hose pump sprayer (Table 2).

**Table 2**. Insecticide solution application, insecticide solution loss, percentage of insecticide solution loss, and time consumption associated with various types of sprayers

| Type of sprayer | Insecticide solution application (L/ha)[/1] | Insecticide solution loss (L/ha)[/1] | Percentage of insecticide solution loss[/1] | Time consumption (h/ha)[/1] |
|---|---|---|---|---|
| Long hose pump (control) | 1,238.3[a] | 359.40[a] | 29.00[a] | 2.01[a] |
| AI drone$_{Nor}$ | 273.1[b] | 0.00[b] | 0.00[b] | 1.11[b] |
| AI drone$_{Hi}$ | 272.8[b] | 0.00[b] | 0.00[b] | 1.11[b] |
| F-test (0.01) | ** | ** | ** | ** |
| CV(%) | 0.32 | 0.43 | 0.00 | 0.22 |

L/ha, liter per hectare; h/ha, hours per hectare, % , percentage; ns, non-significant; CV, coefficient of variation; ** significantly different at 0.01 probability level ($P \leq 0.01$); [1]/in treatment column, the means with the different letter are significantly different at 0.01 probability level ($P \leq 0.01$) as determined by Least Significant Difference (LSD)

### *Cost of chemical insecticide spraying*

The rental price for all three types of sprayers, namely AI drone$_{Nor}$, AI drone$_{Hi}$, and long hose pump, was exactly 27.43 USD/ha for the purpose of spraying chemical insecticide solution in the management of *Allocarsidara malayensis* (Crawford) within the durian plantation (Table 3). Both AI drone$_{Nor}$ and AI drone$_{Hi}$ sprayers incurred the lowest expenses in terms of the employment of laborers (3.82 USD/ha), chemical insecticide usage (4.87-9.72 USD/ha), water consumption (4.5 USD/ha), and electricity consumption (0.41 USD/ha). In contrast, the control (long hose pump) incurred higher costs at 6.91 USD/ha for laborers' employment, 22.06 USD/ha for chemical insecticide usage, 20.41 USD/ha for water consumption, and 2.14 USD/ha for gasoline. The AI drone sprayers, specifically AI drone$_{Nor}$ and AI drone$_{Hi}$, showcased a notable lower gross cost for chemical insecticide spraying, ranging from 42-48% (33.07-37.92 USD/ha), compared to the long hose pump sprayer. Consequently, both AI drone sprayers demonstrated significantly improved work efficiency in comparison to the long hose pump sprayer, as evident by their lower gross cost of chemical insecticide spraying per unit area of durian plantation.

**Table 3.** Simple cost analysis of chemical insecticide spraying by AI drone, and long hose pump to manage *Allocarsidara malayensis* (Crawford) in durian plantation based on the recent data from the year 2023

| Costs | Cost/unit | Unit number | Expenses (USD/ha) | | |
|---|---|---|---|---|---|
| | | | Long hose pump | AI $drone_{Nor}$ | AI $drone_{Hi}$ |
| 1. Rental sprayer (AI drone or long hose pump | 27.43 USD /sprayer/ha | 1 sprayer/ha | 27.43 | 27.43 | 27.43 |
| 2. Labourer (exclusive of meal), 1.72 USD/h, using AI $drone_{Hi}$, AI $drone_{Nor}$, and long hose pump | 1.11, 1.11, and 2.01 h/man-day, espectively | 2 man-day/ha | 6.91 | 3.82 | 3.82 |
| 3. Chemical insecticide (solute) used and its price as sprayed by AI $drone_{Hi}$, AI $drone_{Nor}$, and long hose pump | 17.83 USD/L of chemical insecticide | 0.545, 0.273, and 1.237 L/ha, respectively | 22.06 | 4.87 | 9.72 |
| 4. Water (solvent) used to dilute the insecticide concentration as sprayed by AI $drone_{Hi}$, AI $drone_{Nor}$, and long hose pump | 0.0165 USD/ L of water | 272.5, 272.8, and 1,237.0 L/ha, respectively | 20.41 | 4.50 | 4.50 |
| 5. Electricity use from battery charge for AI $drone_{Hi}$ and AI $drone_{Nor}$; gasoline for long hose pump | 0.1372 and 0.1372 USD/unit, and 1.26 USD/L of gasoline, respectively | 2.99 and 2.99 units/ha, and 1.70 L of gasoline/ha, respectively | 2.14 | 0.41 | 0.41 |
| Gross cost of chemical insecticide spraying (USD/ha) | - | - | 78.95 | 41.03 | 45.88 |

h, hours; USD, United States dollar; 1 USD was equivalent to 36.46 Thai baht (THB) based on 12th of October 2023 (BB, 2023); each sprayer was operated for a duration of 8 hours per day from 0700H to 1200H and from 1400H to 1700H except on a rainy day; 156 durian trees per hectare

## Discussion

The nymphal growth stages of the durian psyllid [*Allocarsidara malayensis* (Crawford)] are highly destructive. In their study, Anutrakunchai *et al*. (2023) discovered that the adult insects of this species deposit their eggs inside the new young leaf tissue. A single egg was observed on a young leaf of a durian tree. The life cycle of a hemimetabolous insect, specifically the durian psyllid [*Allocarsidara malayensis* (Crawford)] is presented in Figure 7. *Allocarsidara malayensis* (Crawford) nymphs and adults feed on the sap of young durian leaves, leading to the development of yellow spots. This hampers the growth of the leaves, causing them to become abnormally small. In severe cases, the affected leaves will curl, dry up, and eventually drop off.

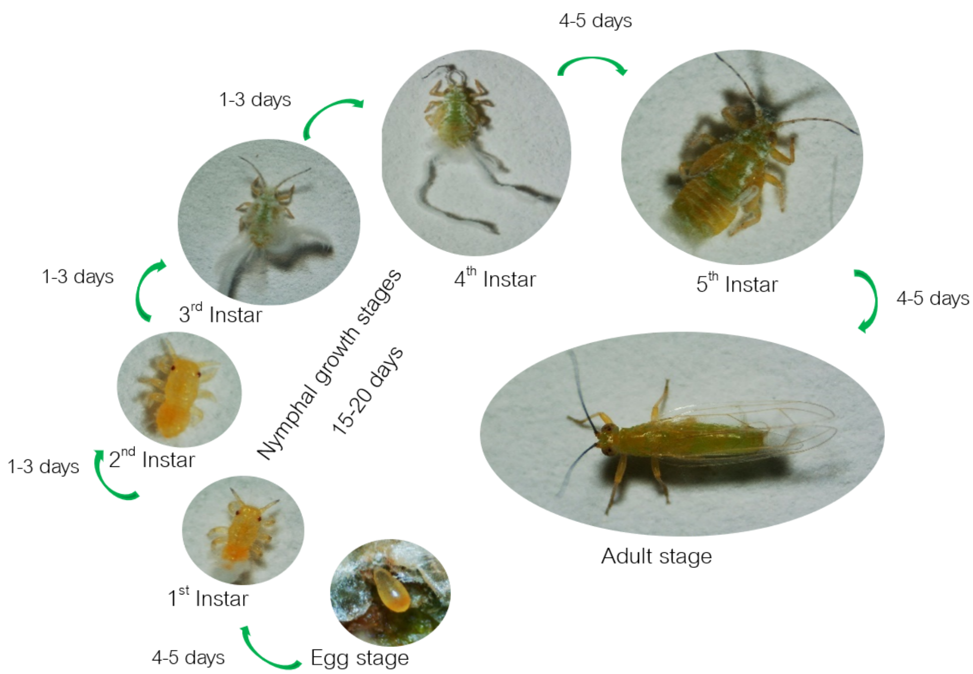


**Figure 7.** Life cycle of a hemimetabolous insect based on a durian psyllid [*Allocarsidara malayensis* (Crawford)] (Anutrakunchai *et al*., 2023)

Based on the research results, it has been discovered that durian psyllids [*Allocarsidara malayensis* (Crawford)] can infest plants at every phase of their growth by sucking the sap from young durian leaves. This suggests that the durian cultivar 'Kradum Thong' is susceptible to infestation by this particular durian psyllid. In line with Percy's (2014) findings, it was observed that the durian psyllids, specifically the durian cv. 'Chanee', lay their egg clusters within the young leaf tissues. Additionally, Kabashima *et al*. (2014) discovered that the development of psyllids from egg to adult occurred within a short span of few weeks, particularly in warm weather conditions. During cool weather, the development and reproduction of psyllids either cease or significantly slow down. Similarly, hot weather has the ability to suppress their populations in certain species. Psyllids typically undergo about 3 to 5 generations per year. Adult psyllids exhibit a characteristic behavior of holding their wings in a rooflike position over their bodies. They measure approximately 1/12 to 1/5 inch in length, which is comparable to the size of large winged aphids. Possessing robust jumping legs and short antennae, they are equipped for agile movement. In contrast, nymphs are flattened and exhibit less activity compared to their adult counterparts. When disturbed, mature psyllids commonly engage in jumping behavior. Furthermore, psyllids possess tubular, sucking mouthparts. High populations of durian psyllids have been found to have detrimental effects on plant growth or caused young leaves to distort and discolor. Durian psyllids could cause premature leaf drop. They cause leaves to develop a pit around the spot where each nymph settles and feeds. *Allocarsidara malayensis* (Crawford), like the durian psyllid, inflicts direct damage to durian trees by feeding on the fresh growth of young leaves. The act of feeding by both nymphs and adults results in the formation of yellow spots on the young leaves, eventually leading to their defoliation. At 3 and 30 days following the application of the cypermethrin insecticide solution (DAS), the utilization of both AI drone$_{Hi}$ and AI drone$_{Nor}$ sprayers led to a notable decrease in the population density of durian psyllids. Additionally, it resulted in a reduced level of damage caused by durian psyllids and a lower occurrence of infestation symptoms. On the other hand, the use of a long hose pump sprayer resulted in a high population density of *Allocarsidara malayensis* (Crawford) and severe infestation symptoms. Consequently, this method proved ineffective in managing the damage inflicted by durian psyllids, as the insecticide droplets were too large to adequately cover the entire leaf surface, unlike the application carried out using the AI drones (Data not shown). Harp (2005) states that cypermethrin exhibits moderate persistence in soils, with its degradation being more rapid in sandy soils as opposed to clay soils and in soils with low organic content (OC). In aerobic conditions, the half-life of cypermethrin ranges from 0.5 to 8 weeks, which is consistend with the conditions observed in the study experimental site. A reduction in the percentage of pupae formation, emergence of adults, and pupal weight was observed when third instar larvae of *P. xylostella* were exposed to a sublethal dose of cypermethrin (Rodríguez *et al*., 2021). To protect plant health, it is important to manage durian psyllids on plants. When controlling these pests, it is recommended to use AI drone sprayers with the right concentration of cypermethrin insecticide, which is 1-2 ml per liter of water, or alternatively, 0.273-0.545 L product/ha or 273-545 ml product/ha, is recommended. It is advisable to opt for insecticide products that are less persistent yet still offer sufficient control, thereby ensuring optimal plant protection. Boht AI drone$_{Hi}$ and AI drone$_{Nor}$ sprayers exhibited the significantly lower population density of durian psyllids and the lower occurrence of infestation symptoms compared to the long hose pump sprayer. The EA-30X model of the AI drone sprayer demonstrated the most significant decrease in insect damage when compared to the long hose pump sprayer during a 60-day period following the spraying. This finding aligns with the Leslie *et al.* (2006) where four field-scale aerial application trials were carried out to control the sugarcane borer (*Eldana saccharina*) by utilizing Fastac (alpha-cypermethrin). The application of Fastac was carried out 6 times (once every two weeks) and 8 times (once every three weeks) on carryover crops from September to December. A microlight aircraft equipped with CDA (controlled droplet application) spray heads was used to apply the insecticide at a rate of 200 ml product/ha. The damage inflicted on the treated cane was significantly lower compared to the untreated cane. The final survey revealed that the estimates for damage were 73% and 67% of the control estimate for the 6 and 8 applications, respectively. Similarly, the numbers of *E. saccharina* were significantly reduced in the treated cane, with estimates being 79% and 76% of the control estimate for the 6 and 8 applications, respectively, based on transformed data (Leslie *et al*., 2006). These findings suggest that aerial application of alpha-cypermethrin can effectively suppress *E. saccharina* infestations, and there is potential for its commercial use in this regard. This study revealed that the implementation of both AI drone$_{Nor}$ and AI drone$_{Hi}$ sprayers, exhibited a significantly superior level of effectiveness in controlling *Allocarsidara malayensis* (Crawford) compared to the use of long hose pump sprayer. This was determined by the evaluation of the minimal population density of *Allocarsidara malayensis* (Crawford), the least amount of insect damage, and the fewest signs of infestation by durian psyllid. However, the durian trees infested with *Allocarsidara malayensis* (Crawford) showed a rapid increase in population density when treated with the control method. This method involved using a long hose pump sprayer (or skid pump). The population density reached 72%, 80%, and 100% at 3, 30, and 60 days after spraying (DAS), respectively. Unfortunately, this led to complete insect damage observed during the same period. This indicates that the long hose pump sprayer was not suitable for applying the insecticide solution. While both the AI drone sprayers exhibited a lower population density of 8-12% and

12-16% within 30 DAS, respectively, it is noteworthy that the highest level of insect damage occurred at 60 DAS. This can be attributed to the fact that each durian tree had new leaves at different times, coupled with the degradation of the cypermethrin insecticide within a month after its application. Consequently, durian psyllids and other insects such as *Clethrogyna turbata* (Butler), *Hypomeces squamosus* (Fabricius), *Thosea* (Walker), and *Hyalarcta huebneri* (Westwood) returned to the treated orchards from the neighboring ones. To eliminate insect infestation, it is recommended to spray cypermethrin with AI drone sprayers during the new leaf growth and development stages. Furthermore, Kuster *et al.* (2023) discovered that employing drones for pesticide spraying greatly minimizes operator exposure in comparison to handheld devices. The utilization of drones can decrease applicator exposure by over 99%, thereby reducing the necessity for extra personal protective equipment (PPE) like impermeable clothing during backpack application, where the operator is in close proximity to the pesticide application. Based on the findings of the Ovako working posture analysis system, it has been established that a minimal risk of musculoskeletal injury is associated with approximately 63.86% of the tasks performed using agricultural drone sprayers (Umeda *et al*., 2022). Drones are becoming increasingly popular in the realm of smart farming due to their ability to swiftly and accurately identify field issues without causing any harm. This is particularly significant as the availability of labor and technical expertise is extremely limited (Subramanian *et al*., 2021). In light of these conditions, the significance of efficient and prompt application of plant protection methods cannot be overstated. In this regard, compact unmanned aerial vehicles offer a multitude of advantages, encompassing enhanced productivity, decreased labor demands, time and energy savings, rapid response capabilities, extensive coverage of large areas, and adherence to environmental safety protocols (Meng *et al*., 2018; Shamshiri *et al*., 2018).

The findings of the study confirm that both AI drone$_{\mathrm{Hi}}$ and AI drone$_{\mathrm{Nor}}$ sprayers are capable of effectively delivering the insecticide to healthy plants. Due to the infested young leaves of the durian cv. 'Kradum Thong' exhibited a rapid recovery when treated with the cypermethrin insecticide. Furthermore, the tested substance, cypermethrin, did not cause any phytotoxic symptoms in the durian trees. Therefore, the utilization of AI drone sprayers for administering cypermethrin has proven to be a highly efficient and effective method for controlling and eradicating the detrimental impact of *Allocarsidara malayensis* (Crawford) in durian orchards. To ensure the overall health of durian trees and minimize infestation by *Allocarsidara malayensis* (Crawford), it is crucial to regularly apply the chemical insecticide solution, containing cypermethrin, to young leaves at 15-day intervals using the AI drone sprayers.

This finding suggests that the utilization of cypermethrin insecticide on durian trees offered effective safeguarding against these destructive organisms.

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