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Effectiveness of Stem Injected Systemic Insecticides on The Development of *Elaeidobius kamerunicus* Faust Larvae In Male Oil Palm Flowers

Khanaya Balqis Haura^{1,*}, Henry Budi Hasibuan¹

Abstract

The pollination process (pollination) in oil palm plants becomes a crucial element in the formation of oil palm fruit. This research aims to examine the effect of systemic insecticide application through stem injection on the development of pollinating insect larvae, *Elaeidobius kamerunicus* Faust, on oil palms. The research was conducted at the Adolina Plantation Unit of PT. Perkebunan Nusantara IV Regional II, Serdang Bedagai Regency, North Sumatra, in January-February 2026. The research used a Complete Randomized Design (CRD) with a factorial arrangement involving two factors: insecticide type (control, Asefat 97% WG, and Tetraniiprol 200SC) and application dose (20, 30, 40 ml per tree). Parameters included *E.kamerunicus* population per bunch and hectare, larval mortality, Growth Index (GI), and Relative Growth Rate (RGR). Data were analyzed with Excel, ANOVA, and Tukey's test at 5% significance using SPSS 22. The results showed that the *E.kamerunicus* population stayed above the minimum threshold of 20,000 individuals, thus not disrupting the ecosystem. The highest larval mortality was observed in the Asefat treatment at 40 ml per tree (24.4%), while Tetraniiprol at 18.5%. The type of insecticide type significantly affected GI values but not RGR values. The results indicated that Tetraniiprol caused lower larval mortality than Acephate, keeping pollinator populations above necessary levels for effective pollination. Therefore, Tetraniiprol can be recommended as a safer alternative for oil palm pest management programs where conserving pollinating insects is a priority.

Keywords: Growth Index, *Elaeis guineensis* Jacq, Mortality, Plantation, Systemic insecticide,

1. Introduction

Palm oil (*Elaeis guineensis* Jacq.) is one of the leading plantation commodities in Indonesia. According to Purwanto (2024), the oil palm plant has become an attractive crop for agribusiness and the promotion of social and economic development. This is also conveyed by Wahyuni and Manurung (2020), who stated that palm oil contributes a significant amount of foreign exchange and serves as a pillar of the national economy.

Generally, in oil palm plantations, pollination is carried out with human assistance (assisted pollination), but this method faces challenges, namely high costs and labor. According to Afrian, Windriyanti, and Wiyatiningsih (2020) to reduce costs, pollination is performed with the help of insects (*entomophily*).

The formation of palm fruit is because oil palms are included in monoecious plants (having both male and female flowers on the same tree). This is also reinforced by Nurkholis, Bara, and Yosephine (2026). who mention in their research that oil palm is a monoecious plant, meaning it bears both male and female flowers on the same individual.

A primary challenge in optimizing oil palm pollination involves maintaining a stable population of pollinating insects within plantation ecosystems. The extensive use of pesticides for pest control can significantly reduce pollinator populations, either directly through mortality or indirectly by impairing their growth and reproductive capabilities. Consequently, this reduction can result in decreased pollination efficiency and an increase in

*Correspondence: Balqiskhanaya298@gmail.com

1) Institut Teknologi Sawit Indonesia - Jl. Willem Iskandar, Kenangan Baru, Kecamatan Percut Sei Tuan, Kabupaten Deli Serdang, Sumatera Utara 20371, Indonesia

parthenocarpic fruit development.

According to Sinaga et al. (2025), the population of *E. kamerunicus* in an area depends on the availability of male flowers that are blooming (*Anthesis*) because they have attractive pollen due to the volatile compounds emitted by each flower, serving as a food source and breeding ground for *E. kamerunicus* beetles.

Palm oil productivity is highly influenced by an efficient pollination process, where *E. kamerunicus* functions as the main pollinator, believed to increase fresh fruit bunch yields, bunch weight, and the number of bunches produced (Romadhon 2023). In a study (Sari and Emmi 2023), the optimal population of *E. kamerunicus* in an area is 20,000 individuals per hectare, with the most productive time being in the morning from 9:00 to 10:00 AM WIB.

Palm oil cultivation faces disturbances like pests, including oil palm leaf-eating caterpillars (such as fire caterpillars, bagworms) and horn beetles, attacking immature (TBM) and mature (TM) plants (Andriani and Okalia 2022). Chemical control, such as stem injection, is used at the pest threshold to deliver insecticide through the plant's vascular system to target pests feeding on oil palm leaves.

This issue is important and aligns with the concept of Integrated Pest Management (IPM), where chemical pesticides are considered a last resort if other methods are ineffective. *E. kamerunicus* pollinators are *monophagous*, acting as host-specific pollinators of oil palms. Its biological characteristics include: *E. kamerunicus* is an insect with complete metamorphosis (holometabola), with egg, larval, pupal, and adult stages (Gintoron et al. 2023)

According to Permadi (2022), the mating (copulation) period lasts 1.84 ± 0.8 days. The pre-oviposition period of *E. kamerunicus* is 2 ± 0 days. The oviposition duration of *E. kamerunicus* is 9.84 ± 0.96 days, with females laying an average of 1.3 ± 0.18 eggs per day. The egg stage of *E. kamerunicus* lasts 2–3 days. The larval stage consists of 3 instars: Instar I lasts 3 ± 4 days, characterized by a very small body, white color, and black spots on the head, which is the mouth; Instar II lasts 2 ± 5 days, characterized by a yellowish-brown color and fine hairs on the body; Instar III lasts 5 ± 6 days, with a bright yellow color, a light brown head, and fine hairs. They obtain food by gnawing at the base of one spike and moving to another, consuming the soft parts of the spike.

Larvae have a curved, C-shaped body, called scarabaeiform. The third instar larva transforms into a pupa, biting the flower spike tip to create an exit for the adult stage. Larvae are more vulnerable to insecticides than adults due to their softer bodies and immature physiology, making them more susceptible to metabolic disturbances from residual active ingredients.

Previous studies have generally examined the impact of insecticides on adult populations (imago) of *E.*

kamerunicus or overall pollinator abundance, such as in the study by Purwanto (2024), which examined the population of *E. kamerunicus* treated with systemic insecticides. In contrast, this research specifically assesses the lethal and sublethal effects of stem-injected systemic insecticides on the larval stage developing within post-anthesis male flowers. This approach offers new insights into the vulnerability of immature stages, which have received limited attention in earlier research.

This research aims to determine the effects of insecticide application via stem injection on the development of *E. kamerunicus* larval stages, identify which insecticide types and doses produce the most lethal and sublethal effects, and determine which are safest for *E. kamerunicus*.

2. Material and Methods

The research was conducted at the Adolina Unit Plantation of PT Perkebunan Nusantara IV Regional II, located in Batang Terap, Perbaungan District, Serdang Bedagai Regency, North Sumatra. In Plantation I with oil palm plants were planted in the same year, namely the 2021 planting year, in block 21R. The plantation area is located at 3,5 LU-98,9 BT.

The research lasted for 2 (two) months, from January to February 2026. A factorial Randomized Complete Block Design (RCBD) with two treatment factors: type of insecticide and application dose.

2.1. Tools and materials

Tools used are an injection drill machine, a syringe, bucket, glass, measuring cup, mask, gloves, face shield, tray, colored tapes, hand saw, hand tally counter, stationery penggar, a millimeter block, and a microscope. The materials used are the insecticides Posthene with the active ingredient Asefate 97 WG, and Vayego with the active ingredient Tetraniliprol 200 SC.

The first factor was the type of systemic insecticide administered via stem injection: A0 (control with no insecticide), A1 (97% WG acephate), and A2 (200 SC tetraniliprol). The second factor was the application dose: B1 at 20 ml, B2 at 30 ml, B3 at 40 ml per plant. These created nine treatment variants to assess insecticide type and dose effects on *Elaeidobius kamerunicus* larvae development on male oil palm flowers.

2.1.1. Preparation research area

The research started with preparing tools and materials and conducting a site survey. A census of male oil palm flowers within the observation block was done to identify available samples. Then, sample trees were labeled for easy identification and monitoring. Before treatment, a population census was conducted to establish baseline data for *E. kamerunicus* per bunch and hectare, serving as a reference for post-insecticide population changes.

2.1.2. Applications of insecticide

Sampled trees were drilled around 1 meter above ground at a 45° angle downward to maximize insecticide absorption into the plant's vascular tissue. The systemic insecticide was applied via stem injection with a syringe, in accordance with the specified treatment type and dosage. The insecticide was injected into the drilled hole until the entire volume was absorbed by the plant. Post-injection, the holes were sealed to prevent solution leakage and contamination from external sources.

2.1.3. Observation

Observations spanned two 21-day periods. The first, 21 days after application (HSA), assessed initial effects of the insecticide on *E. kamerunicus* larval development. The second included another 21 days to evaluate residual or sublethal effects in plant tissues. Both periods monitored larval development parameters to assess how insecticide type and dose via stem injection affected *E. kamerunicus* pollinator populations on male oil palm flowers.

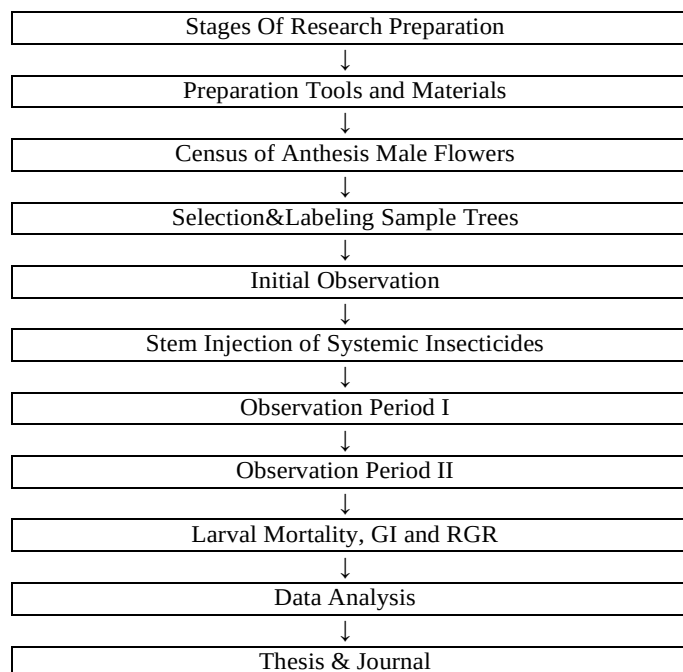


Figure 1. Research flow diagram

2.2. Observation parameters

The parameters observed include:

2.2.1. The population of *E. kamerunicus* per bunch

The percentage of larvae per male flower can be calculated if the number of larvae and the number of male flowers are known, using equation (1) (Huri, Yaherwandi, and Efendi 2022).

$$KT = \sum JKS \times \sum JST \dots \dots \dots [1]$$

Where: KT = number of beetles per bunch

JKS = number of beetles per spikelet

JST = number of spikelets per bunch

2.2.2. Population of *E. kamerunicus* per hectare

It continues with the calculation of the beetle population abundance per hectare to determine whether the land meets the research criteria and is not lacking pollinating insects for testing, using equation (2), which is:

$$PKH = \sum KT \times \sum TBM \dots \dots \dots [2]$$

Where:

PKH = abundance of beetle population per hectare

KT = abundance of beetle count per bunch

TBM = abundance of blooming male flowers

2.2.3. Larval Mortality

The number of larvae that die in each tree unit or male flower at a certain time interval after insecticide injection application, 21 days post-treatment. This is supported by research (Majid Mahmoudi, Pezhman, and Mirab-balou 2020), which also applied the Henderson & Tilton (1955) formula in their study to account for mortality in the control group and estimate mortality due to insecticide treatment. The formula (3) is as follows:

$$\%Mortality = 100 \times \left(1 - \frac{T_a \times C_b}{T_b \times C_a} \right) \dots \dots \dots [3]$$

Where

Tb = the number of larvae before treatment

Ta = the number of larvae after treatment

Cb = the number of larvae before treatment in the control

Ca = the number of larvae after treatment in the control.

2.2.4. Growth index (GI)

is the result of the sum of the stages reached by individual insect larvae under experimental conditions, divided by the product of the number of test larvae (N) and the number of growth stages. The growth used includes all stages from *E. kamerunicus* metamorphosis to pupation (i max) with the following formula (4).

$$GI = \frac{\sum_{i=1}^{i_{max}} (n1 \times i) + \sum_{i=1}^{i_{max}} (n1' \times (i-1))}{N \times i_{max}} \dots \dots \dots [4]$$

Where:

I_{max} = The highest stage that can be reached by the insect (in this research, I_{max} = 4, which is the pupal stage)

i = Number of stages

n1 = Number of larval stages alive at stage i

n1' = Number of larval stages that died at stage i

N = Total number of larvae in the control

2.2.5. Relative Growth Rate Index (RGR)

is the comparison of the relative growth level of an individual within the treatment group to the growth of individuals in the control group. In this research, analytical applications such as IBM SPSS ver.22 and ImageJ were used for data management. The treatment is calculated

using the following equation (5) (Liyana et al. 2022):

$$RGR = \frac{GI \text{ dari suatu perlakuan}}{GI \text{ kontrol}} \times 100 \dots [5]$$

3. Results and Discussion

3.1. Abundance of *E. kamerunicus* Population per Bunch and per Hectare

Conducted a male flower census in Block 21R covering an area of 34 hectares to determine sampling unit points based on the number of oil palm trees to be treated as shown in Figure 2.

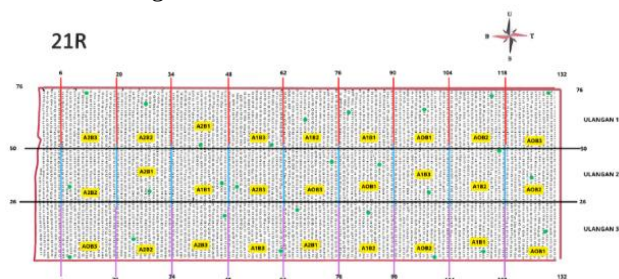


Figure 2. Observation map & sample points

After identifying oil palm trees with male flowers at the anthesis stage, the trees were labeled with cards and colored ribbons on the palm trunk, and the available flowers were recorded. Once the census was completed, the results of flowers at anthesis and post-anthesis in block 21R were obtained, as shown in Table 1.

Table 1. Male flower census data

Blok	Phase			Total
	PraAnt	Anthesis	PostAnt	
21 R	12	9	29	160
	17	10	48	
	12	9	62	

After the flower census, the next step was to calculate the *E. kamerunicus* population abundance per bunch. This calculation result is in accordance with the data analysis using Microsoft Excel. The census results before treatment were used as a reference to calculate larval abundance per cluster and per hectare, as shown in the calculation process in Figure 3.



Figure 3. Process census before treatment

The percentage of larvae per male flower can be calculated if the unit of male flowers has the number of

larvae. The results of the population abundance per bunch and per hectare are shown in Table 2

Table 2. Calculation of abundance per bunch & per hectare

Treat	Abundance per bunch		Abundance per hectare	
	P I	P II	P I	P II
A0B1	1708	2992	461070	807930
A0B2	2758	2978	744660	804150
A0B3	2729	2925	736830	789750
A1B1	2572	2662	694350	718740
A1B2	2541	2457	686160	663390
A1B3	2361	2648	637380	715050
A2B1	2605	2755	703260	743850
A1B2	2589	2769	698940	747540
A2B3	2565	2683	692640	724410

3.2. Mortality (Day After Treatment)

Period 1: after insecticide application, period 2 to observe residual effects after insecticide application in period 1. Then, mortality (death rate) in larvae was observed after stem injection insecticides. The following graph data was obtained.



Figure 5. Physiology change in larvae

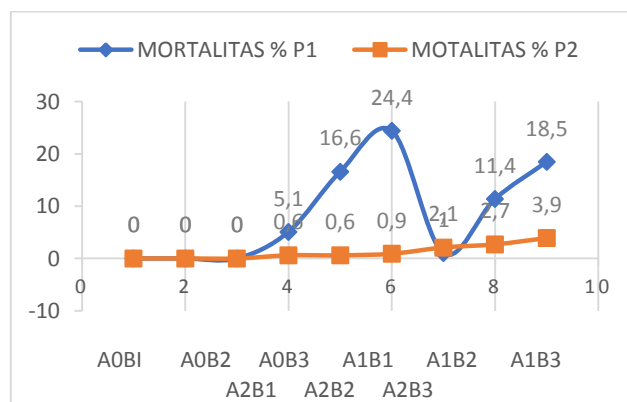


Figure 4. Mortality data Graph

In the data from the graph above, the highest cumulative death data over two periods (24 days) was 24.4% in treatment A1B3 (Asefat dose 40ml), followed by treatment A2B3 (Tetraniliprol 40ml) at 18.5%, A1B2 (Asefat dose 30ml) at 16.6%, and A2B2 (Tetraniliprol 30ml) at 11.4%.

Many physiological changes occurred in *E. kamerunicus* larvae during the 42-day observation, as shown in Figure 5. The most apparent change was in color.

In the control, the larvae were bright yellow, appearing healthy and active. In the asefat larvae, the larvae were dry, brownish, and dead. In the tetraniliprol-treated group, the larvae tended to be pale, small, and active.

3.3. Growth Index (GI)

The Growth Index (GI) value indicates changes in each treatment during the observation period. The GI value reflects the success rate of larvae in reaching higher growth stages, as observed in this research. Starting from Instar 1 larvae to the pupal stage. The higher the IP value, the greater the Larva's ability to continue the developmental process toward the next metamorphosis stage.

Table 3. Results of GI and RGR Calculation

Treat	GI (P1)	GI (P2)	RGR (P1)	RGR (P2)
Control	1,00	1,00	1,00	1,00
Posthene 20 ml	0,666	0,675	1,009	1,015
Posthene 30 ml	0,666	0,678	1,008	1,019
Posthene 40 ml	0,665	0,677	0,993	1,018
Vayego 20 ml	0,660	0,670	1,000	1,007
Vayego 30 ml	0,666	0,668	1,008	1,004
Vayego 40 ml	0,663	0,673	1,005	1,012

Research data can be seen in Table IPR. The results show that the IP value in the first period ranges from 0.663 to 0.666, while in the second period it increases to 0.668 to 0.678. The increase in IP values across almost all treatments indicates that *E. kamerunicus* larvae can continue their growth and development despite exposure to stem injection residues, although there is no significant change.

3.4. Relative Growth Rate Index (RGR)

The parameter of the Relative Growth Rate Index (RGR) is also used to compare the growth ability of larvae in each treatment against the control group. The IPR value reflects the relative growth rate of a population compared to normal conditions (Control), so it can be used to assess how much the treatment affects the biological aspects of the test insects.

Analysis results show that the IPR value in the first period ranges from 0.993 to 1.009 for *Asefate* and 1.00 to 1.008 for *Tetraniliprol*, while in the second period it increases to an average above the control. This increase indicates that the larval growth rate in the treatment groups is getting closer to the control group. This proves that the ability of *E. kamerunicus* larvae to grow and develop recovers after initial stress caused by insecticide residues, although not significantly. Complete data on IP and IPR values can be seen in the table below.

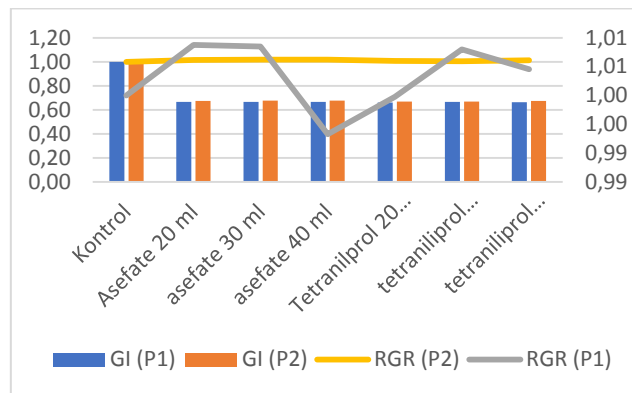


Figure 6. Graph of GI & RGR calculation

Based on observations from the table and graph, insecticide treatments and their doses have different effects on the IP (Growth Index) and IPR (RGR) values of the larvae. The GI value indicates growth inhibition, while RGR describes the post-treatment growth rate.

In the control, both GI and RGR are 1.00, indicating normal growth. The *Asefate* treatment shows a GI lower than the control, ranging from 0.665 to 0, with a dose of 40 ml being the most effective in suppressing larval growth, with an RGR of 0.993. The *Tetraniliprol* treatment has a GI ranging from 0.660 to 0.673, with the 20 ml dose being the lowest, but the effect of the small dose is not significant.

This calculation result is in accordance with the data analysis using SPSS 22 with a Univariate ANOVA test followed by a Tukey post hoc test, and the data obtained are as follows:

Table 4. Analysis in SPSS based on insecticide type

Type Factors	GI (Mean ± Std.Error)	RGR (Mean ± SE)
Kontrol	0,663 ± 0,001 a	1,004 ± 0,003 a
Tetraniliprole	0,667 ± 0,001 ab	1,006 ± 0,003 a
Asefat	0,671 ± 0,001 b	1,010 ± 0,003 a
Sig.	0,001	0,272

Analysis shows insecticide type significantly affects *E. kamerunicus* larvae's Growth Index (GI) ($P = 0.001$), but dose does not ($P = 0.195$). The highest GI was in acephate (0.671 ± 0.001), followed by tetraniliprol (0.667 ± 0.001) and the control (0.663 ± 0.001).

The Tukey test showed that asefat treatment significantly differed from the control, while tetraniliprol did not and was intermediate. For RGR, values ranged from 1.004 to 1.010. Although not significant, asefat had the highest RGR (1.010 ± 0.003), followed by tetraniliprol (1.006 ± 0.003) and the control (1.004 ± 0.003). These suggest that larvae surviving insecticide can grow similarly to the control.

Variance analysis indicates that the dose factor does not significantly affect the Growth Index (GI) or the Relative Growth Rate (RGR) of *E. kamerunicus* larvae,

with significance values of 0.195 for GI and 0.837 for RGR.

Table 5. SPSS-based analysis by insecticide dose

Doses (ML/Trees)	GI (Mean $\pm$ SE)	RGR (Mean $\pm$ SE)
20	0,666 $\pm$ 0,001 a	1,005 $\pm$ 0,003 a
30	0,666 $\pm$ 0,001 a	1,008 $\pm$ 0,003 a
40	0,669 $\pm$ 0,001 a	1,017 $\pm$ 0,003 a
Sig.	0,195	0,837

The GI value ranges from 0.666 $\pm$ 0.001 to 0.669 $\pm$ 0.001. A 40 mL dose per tree yields the highest GI (0.669 $\pm$ 0.001), while 20 and 30 mL doses are similar at 0.666 $\pm$ 0.001. All doses are in the same letter group, indicating no significant difference.

The significant difference is as follows. For the RGR parameter, average values range from 1.005 $\pm$ 0.003 to 1.008 $\pm$ 0.003, with the 30 mL dose showing the highest, but not significantly different. Increasing the dose up to 40 mL per tree does not significantly affect *E. kamerunicus* larvae growth.

Table 6. Tukey's analysis between type and dose of insecticide

Doses (ML/Trees)	GI (Mean $\pm$ SE)	RGR (Mean $\pm$ SE)
Control	0.662 $\pm$ 0.002	1,004 $\pm$ 0,003
Posthene 20 ml	0.670 $\pm$ 0.002	1.009 $\pm$ 0.003
Posthene 30 ml	0,670 $\pm$ 0.002	1.011 $\pm$ 0.003
Posthene 40 ml	0.673 $\pm$ 0.002	1.010 $\pm$ 0.003
Vayego 20 ml	0.666 $\pm$ 0.002	1.005 $\pm$ 0.003
Vayego 30 ml	0.666 $\pm$ 0.002	1.007 $\pm$ 0.003
Vayego 40 ml	0.669 $\pm$ 0.002	1.006 $\pm$ 0.003

Based on the average values from the treatment combinations, the highest GI value was obtained in the asefat treatment with a dose of 40 mL per tree at 0.673 $\pm$

0.002, while the lowest GI value was found in the control with a dose of 20 mL per tree at 0.662 $\pm$ 0.002. In the tetraniliprol treatment, the GI values ranged from 0.666 $\pm$ 0.002 to 0.669 $\pm$ 0.002, indicating a relatively stable larval growth response across all dose levels.

For the RGR parameter, the highest value was in the asefat treatment with a dose of 30 mL per tree at 1.011 $\pm$ 0.003, and the lowest was in the control with a dose of 20 mL per tree at 1.003 $\pm$ 0.003. All treatments produced RGR values close to one, indicating that the larvae were still able to grow and develop normally. This result shows that although certain types of insecticides can affect the GI value, the combination of the type of insecticide and dosage has not yet caused a significant change in the relative growth rate of *E. kamerunicus* larvae.

4. Conclusion

Stem-injected systemic insecticides affected the larvae of the pollinating insect *Elaeidobius kamerunicus* by increasing larval mortality and altering larval development. Acephate showed a greater impact than tetraniliprole, particularly at the highest application dose. The highest cumulative larval mortality was recorded in the acephate treatment at 40 mL tree⁻¹ (24.4%), followed by tetraniliprole at 40 mL tree⁻¹ (18.5%). Although both insecticides affected larval survival, the pollinator population remained above the minimum threshold required for effective pollination.

Based on these findings, tetraniliprole is recommended for use in oil palm plantations because it caused lower larval mortality than acephate while maintaining pollinator populations. The use of tetraniliprole may therefore provide a more environmentally friendly pest management option and support the implementation of Integrated Pest Management (IPM) programs in sustainable oil palm cultivation.

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