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Laboratory efficacy and toxicology of two commercial insecticides (deltamethrin and fenitrothion) against two German cockroach field strains

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ABSTRACT

The German cockroach, *Blattella germanica* (L.), a prominent pest that requires management due to its detrimental economic and medical consequences. Several research discovered that German cockroaches were insecticide resistant, mainly commercial pesticides. One-week-old nymphs from two strains in Penang, Malaysia (Georgetown strain: EL and Greenlane strain: IC strain) were tested in the laboratory against two commercial insecticides, Cislin® 25 (deltamethrin) and Sumithion 50 (fenitrothion). The concentration of solutions used in the residual test based on the manufacturer labeling. Cislin® was tested at 1.90 ppm, 1.60 ppm, 1.30 ppm, and 1.0 ppm; Sumithion 50 was tested at 25 and 27.00 ppm, 23.00 ppm, 18.00 ppm, 14.00 ppm using the residual method. Probit analysis and one-way analysis of variance (ANOVA) were used to compare the data. Cislin® 25 and Sumithion 50 were more effective and high toxicity against the IC strain compared with the EL strain. Sumithion 50 demonstrated a fast knockdown time on cockroaches, but Cislin® 25 showed no knockdown time. Sumithion 50 showed a significant mortality rate in cockroaches within a short period of time compared to Cislin® 25. Both insecticides were found to be effective against both strains, but Sumithion 50 is more effective at controlling cockroaches than Cislin® 25.

1. Introduction

Blattella germanica (L.) is a significant household pest and one of the most common insects in urban environment. Originally believed to be a European native, but this species was later identified as an emergent species from Northeast Africa, and the most recent evidence indicates that it originated in Southeast Asia [1]. Due to its global movement, the German cockroach is a remarkably successful insect pest in several world places, owing to its rapid reproduction, short life cycle, and excellent adaptability [2].

Cockroach populations spreading rapidly in the human environment have resulted in a slew of medical and economic issues. Cockroaches, as is well known, can be important mechanical disseminators of a wide spectrum of infections across geographic boundaries. Various bacterial species, such as non- tuberculous mycobacteria [3] and fungal species, including Aspergillus, Alternaria, Candida, Rhizopus, and Mucor [4] have been stranded from or passed by cockroaches. Allergies and asthma also can be triggered by accidental ingestion or inhalation, cockroach allergens, particularly in children [5–7].

In Malaysia, the German cockroach is the most common species found in hotel kitchens, restaurants, and food preparation areas [8,9]. They are prevalent insect pests of contamination due to their tendency of defecating and regurgitating partially digested foods while feeding. As a result, the presence of this species in hotel kitchens, restaurants, and food outlets may affect the value and revenue of those establishments.

Insecticides have historically been used to control and manage the German cockroach. Pest management professionals employed various approaches, including residual sprays, bait compositions, space treatments, and fumigants. Even though baiting treatment is gaining popularity in Malaysia, residual spray treatment is the primary and most favoured method to pest management businesses [9]. On the other hand, insecticide resistance in the German cockroach has been the topic of multiple reports [2,10–14], posing a substantial problem for pest control companies managing this species. Due to the heavy reliance and high frequency of insecticides usage, resistance to insecticides may develop. It also has developed physiologically based resistance mechanisms such as curtailed cuticular penetration [9], increased in detoxification enzymes [9,10,13], and target site mutation [9,15].

German cockroach resistance was initially reported in Malaysia by [16], who discovered low to high resistance to bendiocarb and

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propoxur, low resistance to chlorpyrifos, and low to moderate resistance to cypermethrin, deltamethrin, permethrin, and phenothrin in field-collected strains. In 2004, Lee et al. [12] observed resistance to propoxur ranging from low to high, chlorpyrifos resistance ranging from low to moderate, and permethrin resistance ranging from moderate to very high. There is no information available on the efficacy of insecticides used in Penang, Malaysia. Indeed, this is an important consideration when developing a management strategy.

In this study, the nymph of the German cockroach was used due to the scarcity of research on this stage. Thus, this research examined the toxicity and efficacy of two commercial insecticides (active ingredient AI: deltamethrin and fenitrothion) towards two strains of nymphs of the German cockroach in Penang, Malaysia.

2. Material and method

2.1. Cockroach collection

Two strains of the German cockroach were gathered in the field from two sites; Georgetown and Greenlane, Penang (Table 1). Cockroaches were collected in damp, warm locations near food supplies, such as the refrigerator and cracks and crevices. The number of individuals varies per site base and is determined by the number of cockroaches that enter the live trap. The German cockroach catching method employed in this investigation was inspired by Kinfu and Erko [17] and Harrell and Davis [18]. Clean, empty jars internally covered with petroleum jelly and wrapped on the outside with crumpled paper were utilized. Inside the trap, a piece of bread dipped in beer was placed. The goal is to create a strong odour that will attract other cockroaches to the trap. Furthermore, the purpose of coating the jars with petroleum jelly is to make the inside slippery, preventing trap cockroaches from climbing out, and the purpose of wrapping the crumpled paper around the outside of the jar is to allow nearby cockroaches to quickly climb up to the trap and come into contact with the bait inside. Each trap was covered with a large opening approximately half the size of the bottle to prevent other animals such as rats from falling into the trap. This procedure enabled the collection of a huge number of cockroaches from the infection sites. After then, the vacuum cleaner was employed to catch German cockroaches.

2.2. Cockroach rearing

All of the cockroaches were reared in plastic aquaria (35 cm by 18 cm by 26 cm) at a temperature of 26–28 °C, relative humidity of 50 %, and a photoperiod of 12:12 h. (L:D). The upper interior surface of plastic aquaria was covered with a dilution of baby oil and petroleum jelly to prevent the cockroaches from fleeing. The cockroaches were provided with an available supply of cat food and water (Fig. 1). For this study, newly emerged nymphs were isolated from the colonies and placed in plastic aquaria.

The experiment was conducted on one-week-old nymphs of F1 generations that had been bred under these laboratory conditions. Numerous biotic factors such as food, age, and time of testing will be standardized for these test insects to eliminate possibility of test result fluctuations [10].

Table 1
Data on field-collected strains of the German cockroach from Penang.

Strain	Collection site	Collection date
EL	Georgetown, Hotel kitchen, Penang	8 Oct. 2019 23 Oct. 2019
IC	Greenlane, Restaurant, Penang	16 Oct. 2019 11 Nov. 2019

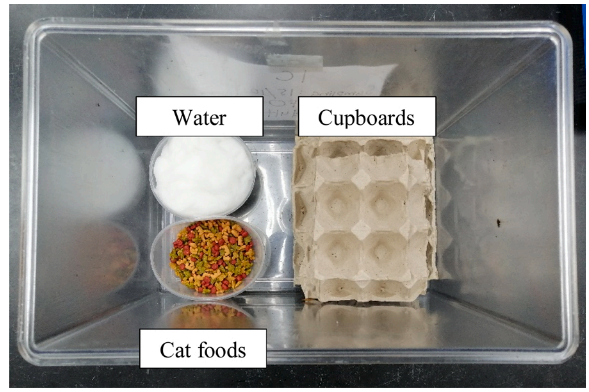

Fig. 1. The cat foods, water and cupboards used in maintaining the German cockroach.

2.3. Cockroach identification

The field-collected cockroaches were identified. Two parallel longitudinal black bands ran vertically across the pronotum of the German cockroach species, separated by a lighter stripe [9]. They were more evident in the adults than in nymphs (Fig. 2).

The nymphs were then identified by their lack of tegmina and wings. The nymph's first half of the dorsum is black with a bright stripe (Fig. 3). Nymphs are characterized by compound eyes, segmented antennae, three pairs of legs, and cerci at the end of the abdomen [2,8,9].

2.4. Insecticide

This experiment utilized Cislin® 25 and Sumithion 50. Cislin® 25 (Deltamethrin; active ingredient = 2.8 %; inert components = 97.2 %) was manufactured by Bayer Environmental Science, Kuala Lumpur, Malaysia. Sumithion 50 (Fenitrothion; active ingredient = 50 %; inert components = 50 %) was manufactured by Agricultural Chemicals (M) Sdn. Bhd. These pesticides were chosen since pest management specialists utilize them, and their resistance mechanisms may differ greatly. The pesticides were dissolved in distilled water to prepare stock solutions. The concentration of solutions used was determined by pesticide manufacturer's label, as shown in Table 2.

2.5. Residual method

Two field-collected strains were evaluated in total. Both experiments used one-week-old German cockroach nymphs, where five nymphs were used in each replicate for each concentration. Three replicates and one control were used for each concentration of each insecticide type. The concentrations used were 1.90 ppm, 1.60 ppm, 1.30 ppm, and 1.00 ppm for deltamethrin (Cislin® 25), and 27.00 ppm, 23.00 ppm, 18.00 ppm,

Fig. 2. The German cockroach adults.

Fig. 3. The German cockroach nymph.

Table 2
The concentration of solutions used in the residual test based on the manufacturer labeling.

Insecticide	Concentration (ppm)
Cislin® 25 (Deltamethrin)	1.90
	1.60
	1.30
	1.00
Sumithion 50 (Fenitrothion)	27.00
	23.00
	18.00
	14.00

and 14.00 ppm for fenitrothion (Sumithion 50). The control groups were treated with distilled water. The tile was the sort of surface employed (15 cm by 15 cm). The pesticides were uniformly sprayed on the tiles and left to dry for 2−3 h (Fig. 4).

Five nymph cockroaches were confined on tile using an inverted plastic container smeared with baby oil and petroleum jelly dilution on the upper surface (Fig. 5).

The knockdown time response was recorded every minute for 3 h. After that, the treated nymphs were placed in a plastic container for post mortality observation. The mortality rates were counted and recorded 3 h, 6 h, 12 h, 24 h after treatment, and until all nymphs died. When a nymph was unable to correct itself within 2 min of being touched on the abdomen with the stick, it considered dead.

2.6. Data analysis

The normality test was used on every replicate to ensure homogeneity between duplicates(2). Then, the data were then pooled and examined using probit analysis [19] to determine the knockdown time (KT); KT50, KT95, LT50, LT95, and lethal dosage (LD); LD50, and LD95 values. Significant differences in the data were determined using a nonoverlap of 95 percent fiducial bounds. Tukey's test was used to differentiate the means of the treatments. Then, a one-way analysis of variance (ANOVA) was used to determine statistically significant differences between the means of separate groups through SPSS version 12.

3. Result

3.1. Comparison of mean (%) number of cumulative mortalities of the German cockroach (Blattella germanica) in EL strain and IC strain

Cislin® 25 and Sumithion 50 were tested on one-week old nymphs to evaluate the insecticides' toxicity and efficacy. Different concentrations of insecticide following the pesticide manufacturer labels were tested on two strains of the German cockroach, and the results were pooled for one-way analysis of variance ANOVA (Table 3). The results were compared on Day 1, Day 3, Day 6, Day 9, Day 12, Day 15, and Day 18.

3.2. Comparison of results between two insecticides in EL strain

Table 3 shows both insecticides were 100 % lethal to nymphs over time. However, Sumithion 50 showed significant toxicity as this insecticide killed all nymphs on Day 1. The mortality number was unaffected by the insecticide's concentrations. Compared to other concentrations, Cislin® 25 at 1.90 ppm started causing mortality on Day 3. However, there was no significant difference in concentrations on Day 6, Day 9, Day 12, Day 15, and Day 18.

3.3. Comparison of result between two insecticides in IC strain

Both insecticides killed all nymphs over time. Sumithion 50 was also highly toxic towards this strain, causing 100 % mortality number on Day 1. For Cislin® 25, there were significant differences between 1.90 ppm and 1.60 ppm on Day 1, and 1.90 ppm also resulted in higher mortality

Fig. 4. Treated insecticide tiles that were dried.

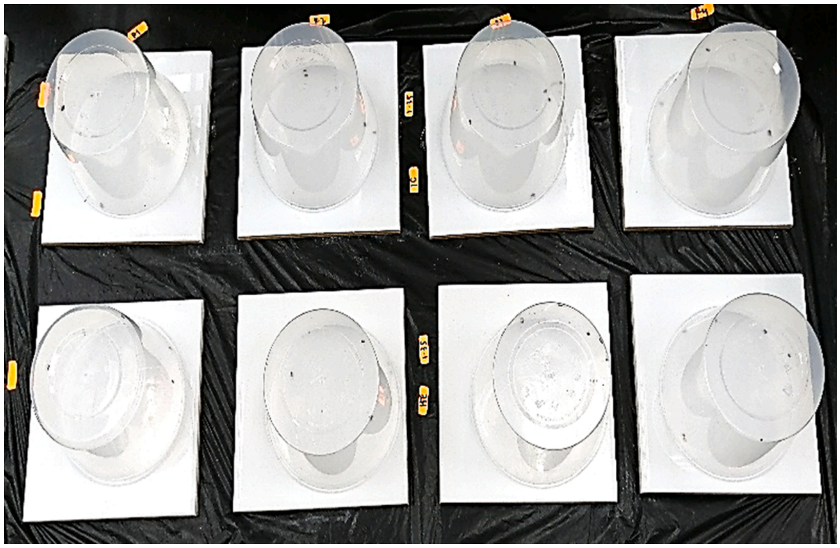

Fig. 5. Residual test method using tiles and plastic containers.

Table 3
Mean (%) number of cumulative mortality (SD±) of the German cockroach (*Blattella germanica*) for EL strain and IC strain.

Strain	Insecticide	Concentration (ppm)	Day 1	Day 3	Day 6	Day 9	Day 12	Day 15	Day 18
EL	Cislin® 25	1.90	0.00 ± 0.00a	13.33 ± 11.55ab	33.33 ± 11.55abc	60.00 ± 20.00bcd	80.00 ± 0.00b	100.00 ± 0.00b	–
		1.60	0.00 ± 0.00a	0.00 ± 0.00a	13.33 ± 11.55ab	46.67 ± 11.55bc	80.00 ± 0.00b	100.00 ± 0.00b	–
		1.30	0.00 ± 0.00a	0.00 ± 0.00a	26.67 ± 11.55abc	40.00 ± 0.00b	73.33 ± 11.55b	93.33 ± 11.55b	100.00 ± 0.00
		1.00	0.00 ± 0.00a	0.00 ± 0.00a	26.67 ± 11.55abc	40.00 ± 20.00b	66.67 ± 11.55b	93.33 ± 11.55b	100.00 ± 0.00
	Control		0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00
	Sumithion 50	27.00	100.00 ± 0.00c	–	–	–	–	–	–
		23.00	100.00 ± 0.00c	–	–	–	–	–	–
		18.00	100.00 ± 0.00c	–	–	–	–	–	–
		14.00	100.00 ± 0.00c	–	–	–	–	–	–
	Control		0.00 ± 0.00a	–	–	–	–	–	–
IC	Cislin® 25	1.90	33.33 ± 30.55b	40.00 ± 20.00c	60.00 ± 20.00c	93.33 ± 11.55d	100.00 ± 0.00c	–	–
		1.60	6.67 ± 11.55a	26.67 ± 11.55bc	46.67 ± 11.55bc	80.00 ± 0.00 cd	100.00 ± 0.00c	–	–
		1.30	0.00 ± 0.00a	20.00 ± 0.00abc	40.00 ± 0.00bc	53.33 ± 11.55bc	80.00 ± 0.00b	100.00 ± 0.00b	–
		1.00	0.00 ± 0.00a	13.33 ± 11.55ab	36.67 ± 25.17bc	60.00 ± 20.00bcd	73.33 ± 11.55b	100.00 ± 0.00b	–
	Control		0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.00a	0.00 ± 0.000a	0.00 ± 0.000a	0.00 ± 0.000a	–
	Sumithion 50	27.00	100.00 ± 0.00c	–	–	–	–	–	–
		23.00	100.00 ± 0.00c	–	–	–	–	–	–
		18.00	100.00 ± 0.00c	–	–	–	–	–	–
		14.00	100.00 ± 0.00c	–	–	–	–	–	–
	Control		0.00 ± 0.00a	–	–	–	–	–	–

*Means within the same column with the same letter are not significantly different (P > 0.05).
*(-) No analysis conducted due to 100 % mortality of the sample.

rate than other concentrations. On Day 3 and Day 6, the concentrations of insecticide were positively correlated with the mortality number of nymphs. However, no significant differences in concentrations were seen for Day 12 and Day 15 (Table 3).

3.4. Comparison of the result between two insecticides in EL strain and IC strain

Table 3 shows Sumithion 50 showed high toxicity towards both strains. All concentrations resulted in a 100 % mortality number on Day

1. Cislin® 25 was more toxic towards IC strain, causing mortality on Day 1 at concentrations of 1.90 ppm and 1.60 ppm, respectively, compared to EL strain. Additionally, this insecticide caused a 100 % mortality number in a short day for IC strains (Day 12 and Day 15) compared to EL strains (Day 15 and Day 18). Concentrations at 1.90 ppm and 1.60 ppm; 1.30 ppm and 1.00 ppm appeared to cause the same 100 % mortality number over time for both strains.

3.5. Knockdown time 50 % and 95 %

According to Table 4, Cislin® 25 had no knockdown time for both strains, even though tested on the nymphs. Oppositely, Sumithion 50 showed longer knockdown time for both strains, implying that Sumithion 50 was more toxic than Cislin® 25. Sumithion 50 had knocked down the nymphs at all concentrations. In the EL strain, the highest concentration (27.00 ppm) and the second concentration (23.00 ppm) showed significant differences in KT50 compared to the other two concentrations. However, no significant variations in KT95 were seen across all concentrations. KT95 was unaffected by different concentrations of this insecticide. Then, only the highest concentration (27.00 ppm) and the lowest concentration (14.00 ppm) of IC strain showed significant differences for both KT50 and KT95. Overall, Sumithion 50 showed the great knockdown time on EL strain compared to IC strain, as KT50 and KT95 of EL strain were lower for each concentration.

3.6. Lethal time 50 % and 95 %

Based on Table 5, all concentrations of Sumithion 50 showed the same lethal time for both strains. Different concentrations of this insecticide did not influence the lethal time of the nymphs. Cislin® 25 at all concentrations had no discernible effect on the EL strain. Nevertheless, the highest concentration (1.90 ppm) revealed theshortest lethal time for the nymphs. Overall, no significant differences for both LT50 and LT95 were seen across all concentrations of this insecticides. Only the highest concentration (1.90 ppm) in IC strain showed a statistically significant difference in LT50 compared to the other concentrations.

Table 4
KT50 and KT95 of the German cockroach (*Blattella germanica*) from. EL strain and IC strain for both Cislin® 25 and Sumithion 50.

Strain	Insecticide	Concentration (ppm)	KT50 (95 % FL)[1] (min)	KT95 (95 % FL) (min)
EL	Cislin® 25	1.90	–	–
		1.60	–	–
		1.30	–	–
		1.00	–	–
	Sumithion 50	27.00	27.26 (24.23–30.12)a	54.11 (47.65–64.53)f
		23.00	39.73 (36.96–42.33)b	58.50 (53.67–66.55)f
		18.00	47.02 (44.01–50.00)c	66.96 (62.49–73.52)fg
		14.00	50.72 (47.56–53.73)c	76.38 (70.51–85.46)g
IC	Cislin® 25	1.90	–	–
		1.60	–	–
		1.30	–	–
		1.00	–	–
	Sumithion 50	27.00	29.65 (27.73–31.41)a	37.03 (34.42–42.65)f
		23.00	41.52 (38.97–43.90)b	56.51 (52.37–63.73)g
		18.00	45.32 (43.07–47.49)b	56.94 (53.41–63.44)g
		14.00	57.03 (54.23–59.73)c	76.32 (71.45–84.20)h

*([1]) 95 % fiducial limit.
*Values within the same insecticide in a strain with the same letter are not significantly different.

Table 5
LT50 and LT95 of the German cockroach (*Blattella germanica*) from EL strain and IC strain for both Cislin® 25 and Sumithion 50.

Strain	Insecticide	Concentration (ppm)	LT50 (95 % FL)[1] (H)	LT95 (95 % FL) (H)
EL	Cislin® 25	1.90	160.20 (142.09–177.47) a	367.49 (317.45–452.46)f
		1.60	212.53 (196.15–228.27)c	363.96 (327.83–423.08)f
		1.30	185.14 (155.51–216.24) ab	599.17 (455.90–949.75) g
		1.00	210.35 (191.06–229.43) bc	438.98 (381.43–539.25) gh
	Sumithion 50	27.00	4.25 (3.49–5.18)d	5.99 (4.95–9.03)i
		23.00	4.25 (3.49–5.18)d	5.99 (4.95–9.03)i
		18.00	4.25 (3.49–5.18)d	5.99 (4.95–9.03)i
		14.00	4.25 (3.49–5.18)d	5.99 (4.95–9.03)i
IC	Cislin® 25	1.90	51.07 (32.82–70.15)a	313.16 (215.94–558.54)f
		1.60	116.54 (96.96–135.14)b	325.58 (268.55–431.02)f
		1.30	149.47 (129.41–168.85) bc	433.86 (360.12–568.24)fg
		1.00	163.11 (143.21–182.07)c	418.26 (354.15–532.57) g
	Sumithion 50	27.00	4.25 (3.49–5.18)d	5.99 (4.95–9.03)i
		23.00	4.25 (3.49–5.18)d	5.99 (4.95–9.03)i
		18.00	4.25 (3.49–5.18)d	5.99 (4.95–9.03)i
		14.00	4.25 (3.49–5.18)d	5.99 (4.95–9.03)i

*([1]) 95 % fiducial limit.
*Values within the same insecticide in a strain with the same letter are not significantly different.

LT95 appeared to be non-significant in this strain at all concentrations. Sumithion 50 was highly toxic to both strains, as all the concentrations had a short knockdown time compared to Cislin® 25. Sumithion 50 expressed LT50 and LT95 within 24 h, although Cislin® 25 did not. Then, Cislin® 25 was highly toxic to the IC strain, with each concentration had a shorter lethal time than the EL strain.

3.7. Lethal dosage 50 % and 95 %

Based on Table 6, Sumithion 50 did not have lethal dosage, as all nymphs tested at different concentrations exhibited 100 % mortality on Day 1. It is proposed that the lethal dosage of this insecticide be reduced from the tested concentrations. For Cislin® 25, IC strain had a lower lethal dosage than the EL strain. There was a significant difference in this insecticide between these two strains.

4. Discussion

The German cockroach, *Blattella germanica* (L.), is still managed using conventional insecticides. Pest management professionals tackle

Table 6
LD50 and LD95 of the German cockroach (*Blattella germanica*) from EL strain and IC strain for both Cislin® 25 and Sumithion 50.

Strain	Insecticide	LD50 (95 % FL)[1] (ppm)	LD95 (95 % FL) (ppm)
EL	Cislin® 25	1.58a	14.05f
	Sumithion 50	–	–
IC	Cislin® 25	0.99b	2.50g
	Sumithion 50	–	–

*([1]) 95 % fiducial limit.
*Values within the same insecticide in a strain with the same letter are not significantly different.

this pestiferous insect with several chemical classes and formulations. Much of the research on insecticidal toxicity and efficacy has been done on adult cockroaches, but little is known about this species' nymphs [20]. Insecticidal toxicity and efficacy on nymphs should be studied as well, as insecticides used in the field expose all stages of cockroaches. Furthermore, laboratory research on the efficiency of insecticides on German cockroaches at the nymphal stage is lacking compared to the adult stage [20].

In this study, one-week-old nymphs were used. Nymphs have less body fat at this stage to inhibit the insecticide compounds from reaching the target cells [21]. Reduced body fat also affects the nymph metabolism as body fat stores of toxic substances in the body [22], acts as a natural filter, and acts as a barrier against insecticides [21]. Theoretically, nymphs are more susceptible to insecticides. Therefore, reducing the toxicity and efficacy of insecticides used against nymphs may result in control failures [21].

According to the data, both strains responded differently to pesticides. Cislin® 25 and Sumithion 50 demonstrated substantial toxicity against the IC strain than the EL strain. The fact that these two insecticides have such a wide range of effects on both strains suggests that they have diverse insecticide tolerances. According to management, in comparison to the EL strain, the IC strain received insecticide treatments less frequently. During the collection of samples, no pest management professionals conducted management controls against the IC strain (or the exposure level of pesticides was comparably low), although many management controls had been done against the EL strain. There was a possibility that the EL strain developed resistance to Cislin® 25 and Sumithion 50, which explained the observed differences between these two strains.

According to Tabashnik et al. [23], resistance is genetically determined by features that allow insects to withstand insecticide dosages that are lethal to other individuals of the same species. This is a common occurrence in German cockroach populations, and, unsurprisingly, some types are resistant to 8–12 pesticides. This occurrence may be attributed to the high frequency of application and a wide range of chemical insecticides.

The results of this study were also supported by Bong et al. [24]. This study revealed that *Paederus fuscipes* strains that were repeatedly exposed to developed resistance and reduced the efficacy of the insecticides. This phenomenon also occurred among other *Coleoptera*, such as *Leptinotarsa decemlineata,* resistant to pyrethroid and organophosphate [25], and *Listronotus maculicollis,* which was resistant to pyrethroid [26]. Mohsen et al. [27] discovered that the D strain of *B. germanica* was more resistant to carbamate and pyrethroid than the H strain. The test was performed using the standard dose, and it was determined that D strain exhibited more excellent pesticides resistance than the normal dose. Thus, these findings proved that tolerance of the EL strain to insecticides might occur as a result of a wide range of chemical insecticides used and high frequency of insecticides application.

Compared to Cislin® 25, Sumithion 50 demonstrated significant potential for German cockroach control in this laboratory assessment. Sumithion 50 showed a rapid knockdown time (Table 4) and a high mortality rate in a short time, despite its use at lower doses. Cislin® 25 had deltamethrin as its active component, while Sumithion 50 contained fenitrothion. Deltamethrin is a pyrethroid insecticide in general, and this class of pesticide is highly favoured by pest management professionals for management controls. This is the safest class of insecticides used to control and prevent a range of household pests, including cockroaches, spiders, ticks, fleas, and bed bugs [24]. Fenitrothion is a less preferable insecticide due to its stains on the treated surfaces and has a pungent odour. However, this insecticide is known to have a rapid effect on targeted insects with a long duration of residual effects.

Based on the results, Sumithion 50 showed superior performance against both strains (Tables 4 and 5). Nymphs of both strains were highly susceptible to this insecticide, as these strains had not previously exposed to organophosphate class insecticide and thus, had a poor potential for resistance development. Moreover, the characteristics of this insecticide, such as rapid action and lengthy residual effect, especially on the non-porous surface may have contributed to this result.

The findings of Mohamed et al. [28] on male and female rats validated the findings of this investigation. According to the study, this insecticide possessed acute toxicity and the potential for application in pest management control due to its ability to eliminate all rats within 48 h. According to Abd-rabou and Moustafa [29], this insecticide had high efficacy against *Maconellicoccus hirsutus* and its natural enemies in laboratory studies, ranging from 58 percent to 98 percent, and high efficacy against these species in field studies, ranging from 88 percent to 96 percent. Fenoxythion was found to be more effective than the other three product insecticides. Lukwa et al. [30] investigated *Blattella germanica* and *Periplaneta americana* density number following exposure to fenitrothion and lindane and discovered that fenitrothion was highly harmful to *B. germanica* and *P. americana*. After pesticide applications, *B. germanica* population density was reduced by 87.8 %, while *P. americana* population density was reduced by 83.8 %. Fenitrothion also had a three-month residual effect in this investigation when to lindane, as both cockroach nymph species had 100 % mortality after the post-spray treatment. These tests demonstrated that this insecticide class was highly effective against a wide range of target species, and that its minimal application resulted in poor species tolerance.

Cislin® 25 was ineffective against both strains, although the highest insecticide label dose is intended to kill nymphs quickly. In comparison to Sumithion 50, Cislin® 25 did not achieve favourable results in this trial. According to Doggett and Russell [31], field strains of *Cimex lectularius* demonstrated lower mortality when tested topically with Cislin® 25 than other pyrethroid insecticides. *C. lectularius* developed resistance to this insecticide due to its high reliance on and frequent application. Due to the widespread use of pyrethroid insecticide against particular strains, a study by Syed et al. [32] on the toxicity of insecticide formulations from different classes against *P. americana* revealed that deltamethrin demonstrated moderate to high levels of resistance compared to fipronil. Due to the frequent use and application of pyrethroid insecticides in both strains, this investigation placed high level of selection pressure on both EL and IC strains. Both strains have previously been treated with pyrethroid active ingredients and formulations in a variety of combinations. Although Cislin® 25 was never applied in both strains, cross-resistance to this pesticide has been found in a number of cases. This conclusion is consistent with Chai and Lee's [10], who discovered that resistance to deltamethrin in Singapore was almost certainly resulted in cross-resistance to beta-cyfluthrin, although beta-cyfluthrin was never administered in any of the locations. The study used a topical bioassay to test novel and conventional insecticides from six different classes. Since both active components were pyrethroids, alternative pyrethroid insecticides could develop cross-resistance with deltamethrin, even though Cislin® 25 was never employed against both strains in the study.

Finally, it was discovered that varying pesticide concentrations did not affect the nymph's response in this trial. Cislin® 25 (1.90 ppm, 1.60 ppm, 1.30 ppm, 1.00 ppm) exhibited a low death rate and a short knockdown duration in both strains, but Sumithion 50 (27.00 ppm, 23.00 ppm, 18.00 ppm, 14.00 ppm) had a high mortality rate and a longer knockdown time. The efficacy of Cislin® 25 may affect greater detoxification capacity in resistant nymphs since Koehler et al. [33] claimed that reduced nymph response was prominent when resistance strains exhibited enhanced detoxification capacity. Neither a very high nor a very low concentration of insecticide would have significant effect on nymphs. Finally, this species is remarkable for its necrophagous, emetophagous, and coprophagous. When intoxicated carcasses are digested and uninfected nymphs contacted with the excretions contain very lethal pesticides, intoxicated nymphs will infect others. This is especially true because, following treatment, the fatal time for different concentrations of Cislin® 25 on both strains indicated a considerable difference.

5. Conclusion

Both insecticides were found to be efficient effective against both strains. However, according to this laboratory investigation, Sumithion 50 successfully suppressed the German cockroach on both EL and IC strains. The minimal insecticide concentration recommended by pesticide manufacturers could result in rapid knockdown and fatality. This is possible because the organophosphate insecticide class is less popular among pest management specialists than other insecticide classes. Cislin® 25 is less effective in suppressing this species on both strains. Even at the highest insecticide concentrations, no knockdown occurred, and cockroach mortality took longer than Sumithion 50. Then, when comparing the IC and EL strains were compared, Cislin® 25 demonstrated a lower lethal dosage for the IC strain, while Sumithion 50 lacked a lethal dosage since all cockroaches tested at various concentrations died on Day 1.

Conflict of Interest

The authors declare no conflict of interest.

Author statement

Author Contributions: Q.A.S., A.H.A.M. designed the experiment; Q.A.S. collected data; analyzed the data and wrote the manuscript, A.H.A.M. read, corrected, and approved the manuscript. All authors have read and agreed to the published version of the manuscript.

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Declaration of Competing Interest

The authors report no declarations of interest.

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