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Effectiveness of a commercial insecticide (Deltamethrin) against laboratory and field population of German cockroaches from Bukittinggi, West Sumatera

Resti Rahayu* and Reni Pusvitasari

Animal Physiology Research Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Andalas University, Padang, West Sumatera, Indonesia 25163

ABSTRACT

This study examined the effectiveness and repellency value of the commercial insecticide initial "KB" (Deltamethrin [0.6%]) to the German cockroaches. The research was performed by contact toxicity and repellent bioassay method using two populations; VCRU-WHO and RMKN-BKT. The effectiveness criteria are based on the value of knockdown time (KT) and lethal time (LT) that refers to the Directorate of Fertilizers and Pesticides of Indonesia, 2004. Results demonstrated that "KB" is effective in paralyzing the German cockroaches of VCRU-WHO (KT90 = 11.09 min) but ineffective in killing the population (LT90 = 43.65 h). This product is also ineffective either in paralyzing or killing the RMKN-BKT population (KT90 = 43.6 min, LT90 = 71.46 h). The repellency of "KB" is low in both populations and the resistant ratio value (RR50) revealed that RMKN-BKT has a low resistance to "KB".

Key words : *Blatella germanica* L., contact toxicity, pyrethroid insecticide, resistance, repellency.

INTRODUCTION

Due to the losses incurred both in the health and economic fields, cockroaches are insects that get more attention in controlling their population. To date, synthetic insecticides are still the primary option to manage insect pests (Indiati, 2017). Many synthetic insecticide products are available in public. However, the reports regarding the effectiveness of the product are still limited. In Indonesia, one of the commercial insecticides which are widely on the market is insecticide chalk initial "KB". Insecticidal chalk is a household insecticide formulation that is involved in controlling the population of ants and cockroaches (Meftaul *et al*., 2020). Insecticide "KB" is popular but its effectiveness against insect pests especially German cockroaches is still unknown.

As one of the tourist cities in West Sumatra, Bukittinggi is often visited by both domestic and foreign visitors. Unfortunately, German cockroach populations are still found in public places such as hotels and restaurants. Surely, it disrupts comfort and can affect the health of the visitors. Further, this study will determine the effectiveness of the insecticide "KB" against German cockroaches in Bukittinggi population, both its ability to paralyze and kill this pest.

MATERIALS AND METHODS

This research was conducted at the Animal Physiology Laboratory of the Biology Department, Andalas University, Indonesia. The German cockroach (*Blattella germanica* L.) used were the standard population (VCRU-WHO) and field population (RMKN-BKT) from Bukittinggi, West Sumatra. The rearing of German Cockroaches populations refers to Ahmad and Suliyat (2011). Cockroaches were reared in 16-liter plastic containers and they were fed with cat food (*pedigree*) and watered *ad libitum*. The laboratory rearing was conducted under the temperature of 25-28°C, the humidity of 70-95%, and a 12:12 photoperiod. This experiment was used adult male cockroaches (Fig. 1).

This experiment used commercial insecticide initial "KB" or known as "miraculous insecticide chalk" with Deltamethrin (0.6%) as the active ingredient. The contact method was performed by adopting the daily application of insecticide chalk.

*Corresponding author's E-mail : restirahayu@sci.unand.ac.id

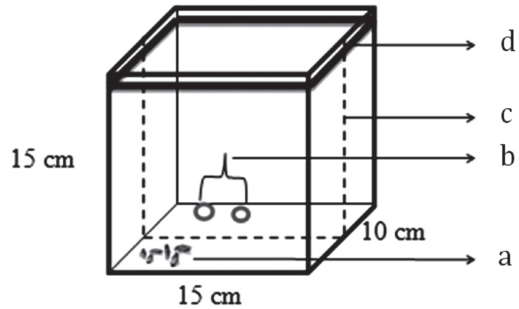

Fig. 1. Schematic drawing of contact method, (a) German cockroaches, (b) food and water of cockroaches, (c) insecticidal chalk scratch, (d) vaseline.

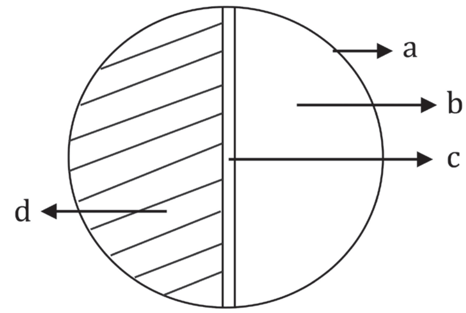

Fig. 2. Diagram of repellency test: (a) Petri dish, (b) Control-side, (c) Cockroach release area, (d) Treated-side.

The experiment was carried out in an aquarium (15 × 10 × 15 cm) which was equipped with feed (pedigree) and drink (wet cotton). Each edge of the top side of the aquarium was smeared with vaseline and baby oil then insecticidal chalk is scratched twice on each centerline of the aquarium which divides the aquarium into two equal parts. Ten male cockroaches for each strain were placed into each provided aquarium. Knockdown time (KT) and lethal time (LT) were observed every minute for 10 min, every 10 min for 60 min, every h for 6 h, 24 h, every day until mortality > 80% or a maximum of 2 weeks. Cockroach knockdown is a condition where the cockroach can no longer move from one point to another, but the legs still move when touched, while lethal is a condition where the cockroach cannot move at all (Directorate of Fertilizers and Pesticides, 2004) .

The repellency method referred to a combination of Ferrero *et al.* (2007) and Manzoor *et al.* (2012). The experiment was carried out in several stages using sublethal concentrations. First, circular white filter papers (15 cm diameter) were divided into two halves. One of the halves was treated by scratching the chalk once on it and the other half was untreated (control). The treated filter paper was spaced 1 cm from the control filter paper. Ten male cockroaches were freed in the center of the petri dish (Fig. 2), and their distribution was recorded firstly in 10 minutes, then, periodically every 1 hour for 6 h, and after 24 h. Repellency value (RV) was determined based on Thavara *et al.* (2007) as below:

$$\text{Repellency (\%)} = 100 - \frac{[T \times 100]}{N}$$

Where T, is the number of cockroaches located in the treated area; and N is the total number of cockroaches used.

The percentage repellency is classified according to Dales [3] as below:

Class 0: <0.1 (Non-repellent) Class I: 0.1 - 20% (Very low)
Class II: 20.1 - 40% (Low) Class III: 40.1 - 60% (Medium)
Class IV: 60.1 - 80% (High) Class V: 80.1 - 100% (Very high)

The knockdown time (KT) and lethal time (LT) from the treatment were analyzed by probit using the Minitab 17 program to obtain the KT90 and LT90 values. The criteria for the insecticides' effectiveness were determined from the Directorate of Fertilizers and Pesticides of Indonesia. Insecticide "KB" was categorized as effective if the KT90 of the German cockroach population can be achieved for a maximum of 20 min after exposure to the insecticide and the LT90 of the German cockroaches can be reached a maximum of six hours after exposure (Directorate of Fertilizer and Pesticides, 2004).

RESULTS AND DISCUSSION

The first paralysis of German cockroaches after being treated with commercial insecticides "KB" started in the first 10 min for the VCRU-WHO population but it took slightly longer for the RMKN-BKT population where the paralysis started in the first 20 min (Table 1). The first paralysis percentage of the VCRU-WHO and RMKN-BKT population were 88 and 24%, respectively. The time of paralysis of 90% of German cockroaches from the VCRU-WHO and the RMKN-BKT population took place in 10 and 50 min, respectively. The highest incidence of mortality in the VCRU-WHO population took place within 24 to 48 h after treatment (66%) while it took place within 48 to 72 h after treatment in the RMKN-BKT population (64%) (Table 2). These results showed that it took longer to kill the cockroaches from RMKN-BKT compared to the VCRU-WHO population.

Table 1. Mean of knockdown time of German cockroaches after insecticide treatment by contact toxicity method in tested populations.

Time (min)	Mean of paralyzed cockroaches ± SD (n = 10)	
	VCRU-WHO	RMKN-BKT
10	8.80 ± 0.45	0.00 ± 0.00
20	9.80 ± 0.45	2.40 ± 0.55
30	9.80 ± 0.45	5.20 ± 1.64
40	10.00 ± 0.00	7.40 ± 1.52
50	–*	10.00 ± 0.00
60	–*	–*

*There is no observation because the mortality has reached 100%.

Table 2. Mean of cockroach mortality per hour after insecticide treatment by contact toxicity method in tested populations.

Time (h)	Mean of cockroach mortality ± SD (n = 10)	
	VCRU-WHO	RMKN-BKT
1	0.00 ± 0.00	0.00 ± 0.00
2	1.00 ± 0.00	0.00 ± 0.00
3	1.80 ± 0.84	0.20 ± 0.45
4	2.20 ± 0.84	0.40 ± 0.89
5	3.00 ± 0.71	0.60 ± 0.89
6	3.20 ± 0.84	0.60 ± 0.89
24	3.40 ± 0.55	1.80 ± 0.45
48	10.00 ± 0.00	3.60 ± 1.52
72	–*	10.00 ± 0.00

*There is no observation because the mortality has reached 100%.

The death of the cockroach was caused by the presence of deltamethrin in the insecticide chalk. As the active ingredient in the insecticide “KB”, deltamethrin is known to kill insects through dermal contact and also digestion. Deltamethrin affects the peripheral and central nervous systems of insects, its action through sodium channels, prolongs the duration of sodium channel opening, stimulates nerve cells to produce repeated discharge, then causes paralysis, and finally death (Matsumura, 1985). The mode of action of deltamethrin in the nervous system is by inhibiting the axons contained in the ion channel by binding to the voltage-gated sodium channel (VSGC) protein which functions in regulating nerve impulses so that action potentials occur continuously (Martins and Valle, 2012). Table 3 represented that “KB” insecticide was able to give a rapid knockdown effect on German cockroaches from the VCRU-WHO population but not so for the RMKN-BKT population. The results of the contact method in the tested populations showed that the RMKN-BKT population took almost twice as long to reach LT90 compared to the VCRU-WHO population. The difference is probably because RMKN BKT is a field population that may have been previously exposed to various classes of insecticides including pyrethroids. Besides, the use of insecticides from the same group or different groups but having a similar mode of action can still cause resistance known as cross-resistance (Brogdon and McAlister, 1998).

Furthermore, the knockdown time data showed that the slope value of the RMKN-BKT population is higher than that of the VCRU-WHO (Table 3). It indicates that individuals in the RMKN BKT population are more homogeneous than individuals in the VCRU-WHO population. A lower variation of individual cockroaches will give a homogeneous response to insecticides and a simultaneous death response at the time of observation. The more gradual the response to the mortality of the cockroach population to insecticides, the higher the individual variation in the population.

The resistance ratio value revealed that the RMKN-BKT population is already resistant while VCRU-WHO is susceptible. RMKN-BKT has been resistant to the category of a low level (Table 4). The existence of resistant insects is triggered by prolonged exposure to certain insecticides so that the insects develop a defense system against the insecticide that is often used (Lima *et al*., 2011). Based on the surveys, almost all household insecticides use pyrethroid as the active ingredient (Sigit and Hadi, 2006). It means household pests including cockroaches have likely been exposed to

Table 3. The effectiveness of insecticide “KB” based on the knockdown time and lethal time in tested populations.

Population	KT_{90} (min)	Criteria*	Slope ± SE	LT_{90} (h)	Criteria*	Slope ± SE
VCRU-WHO	11.09	Effective	0.02 ± 0.22	43.65	Ineffective	0.13 ± 1.21
RMKN-BKT	43.6	Ineffective	0.25 ± 1.76	71.46	Ineffective	0.12 ± 1.08

*Based on Directorate of Fertilizers and Pesticides (2004)

Table 4. The resistance ratio value (RR50) of the cockroach against insecticide "KB" in each population.

Population	RR_{50}	Criteria*
VCRU-WHO	1	Susceptible (RR50 ≤ 1)
RMKN-BKT	2.14	Low resistance (1 < RR50 ≤ 5)

*Based on Lee and Lee (2004)

Table 5. Repellency of insecticide "KB" against German cockroaches in each population.

Population	1 h (%) ± SD	6 h (%) ± SD	24 h (%) ± SD	Category*
VCRU-WHO	12.00 ± 10.95	30.00 ± 7.07	34.00 ± 5.48	Low
RMKN-BKT	14.00 ± 11.40	36.00 ± 11.40	22.00 ± 8.37	Low

*Based on Dales (1996)

high-frequency pyrethroid insecticides. The more frequent the use of insecticides and the higher the dose used, the faster the selection process for resistant individuals (Brogdon and McAlister, 1998).

Insecticide resistance occurs because insects can avoid and detoxify the active ingredients of insecticides that enter the body and the presence of genetic mutations. Each insect species has a different resistance mechanism in dealing with various insecticide selection pressures (Rahayu, 2011). The resistance mechanism that is often found in *B. germanica*, especially against pyrethroid also DDT insecticides, is the decreased sensitivity of target cells to insecticides due to mutations in certain genes known as knockdown resistance (kdr) (Dong *et al*., 1988). Although the resistance of the RMKN-BKT population is relatively low (Table 4), formulating a strategy to suppress the rate of resistance development is crucial. Otherwise, resistance will encourage the use dosage and application of higher insecticides and can pose a bad risk to human health (Rahayu, 2011).

Against the population of VCRU-WHO and RMKN-BKT, the commercial insecticide "KB" showed low repellency. The repellency values of these two populations are also not significantly different (Table 5). It seems that there was no repellent effect wherein the cockroaches move freely even in treated areas during the observation. Most likely, the low repellency is caused by several disadvantages that chalk formulation insecticides have, including: easily drifting off target during the application, residue easily moved off-target by air movement or water, will not stick to surfaces as well as liquids, and being difficult to get an even distribution of particles on surfaces (Fishel, 2009).

This study showed that not all commercial insecticides were effective in controlling pests. Especially for the RMKN-BKT population, several brands of commercial aerosol insecticides are still effective in paralyzing the cockroaches even though these products are no longer effective at killing this population (Rahayu *et al.,* 2021). Therefore regarding its effectiveness, any commercial insecticide requires further evaluation.

To prevent the development of resistance cases, the use of insecticides requires six important aspects that must be considered including (1) right on target, (2) right quality, (3) right type, (4) right time, (5) right dose or concentration, and (6) proper way of use (Directorate General of Horticultural Production Development, 2002). Along with the six aspects, rotation of the use of insecticides can also reduce the rate of development of insecticides on insect pests. The use of plant-based insecticides such as papaya (Rahayu *et al.,* 2020), noni (Rahayu *et al*., 2021), and citronella grass (Jannatan *et al*., 2017; Rahayu *et al*., 2015) can also be considered in controlling this pest.

AUTHORS' CONTRIBUTION

Conception or design of the work (RR); Data collection (RR, RP); Data analysis and interpretation (RR, RP); Drafting the article (RR, RP).

DECLARATION

The authors declare that they have no conflict of interests.

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