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A comparative study of the efficacy of cockroach gel bait insecticides used in Thailand

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Abstract
Cockroach is an insect in the order Blattodea which around 30 species are associated with human habitats and well-known as insect pests including American and German cockroaches. The main objective of this study is to examine the efficiency of some gel baits insecticidal products in the Thai markets that can affect mortality rates and attraction rates of two species of cockroaches: American cockroach (*Periplaneta americana*) and German cockroach (*Blattella germanica*) under laboratory conditions. The bio-efficiency of two selected gel baits insecticidal products used for cockroach control was conducted against and compared between adult males and females of the American cockroach (*Periplaneta americana*) and the German cockroaches (*Blattella germanica*) to determine the mortality rates at 0, 5, 15, 30 min., and 1, 3, 6 12, 24 and 48 hours, respectively, then the effectiveness of each type of gel baits had been compared each other. Test substances were Acephate 3% w/w and Dichlorvos 1% w/w by testing at dosages of 0.1 and 0.25, g a.i./m^2. Treatment rates were determined according to World Health Organization (WHO) testing recommendations or product label instructions. These products were tested separately against *P. americana* and *B. germanica* using surface contact exposure method. From the analysis, Acephate 3% w/w had the mortality rate at 95% whereas Dichlorvos 1% w/w had the mortality rate at 75% both in American cockroaches and German cockroaches. Toxicity comparison of the two insecticidal products examined against *P. americana* and *B. germanica* decreased in the order of Acephate and Dichlorvos. In the attraction experiment, Imidacloprid 2.5% w/w had the attraction rates at 5.1±0.05 individuals per day whereas Nano boric acid had the attraction rates at 3.07±0.12 individuals per day which was the lowest level of attraction.

Keywords: cockroaches, gel bait, insecticides, chemicals

Introduction

The American cockroach, *Periplaneta americana*, is the largest species of cockroach. It is often considered as an insect pest and known as the ship cockroach, kakerlac, and Bombay canary (Bell and Adiyodi, 1981) [2]. The German cockroach, *Blattella germanica*, is another important urban insect pest. It is a vector of several pathogens such as bacteria and viruses. The inhalation or ingestion of their fecal or saliva may cause asthma and allergies (Lee and Ng, 2009). To control these cockroaches, chemical insecticides application remain the most effective method. Nevertheless, a high frequency of use these chemicals and a heavy reliance on insecticide treatments have caused the resistance development to many classes of insecticide such as carbamates, oxidiazines, phenylpyrazoles, organophosphates and pyrethroids (Lee and Lee, 2004; Chai and Lee, 2010; Gondhalekar and Scharf, 2012; Moemenbellah-Fard *et al.*, 2013) [11, 5, 7].

Insecticides resistance in *P. americana* and *B. germanica* has become a major trouble for the pest management and control. Acephate, Dichlorvos, Fipronil, Imidacloprid and Nano boric acid have been widely used against both insecticide resistant and susceptible strains of those cockroaches in laboratory experiments, especially in the form of gel bait (Nasirian, 2008) [15]. Many types of gel baits are highly effective in both American cockroach and German cockroach infested human house where control with other insecticides failed because of resistance (Nasirian, 2008) [15]. The dust boric acid, and gel baits containing boric acid are effective in killing the cockroaches. They are effective and low risk to animal, human health, and environment (Zurek et al., 2003) [19]. The synergism between *Metarhizium anisopliae* and boric acid against German cockroach was also studied by Zurek *et al.* (2002) [20] which the results showed that *M. anisopliae* killed cockroaches significantly faster than no boric acid.

Acephate is classified as an organophosphate insecticide. It works by eating or touching from insect pests. When these pests ate it, Acephate would turn into methamidophos which is very toxic to insect pests but less toxic in mammals (Mahajna *et al.*, 1997) [12]. Dichlorvos and Chlorpyrifos are classified in the organophosphate insecticide group. They are highly toxic and affect the monooxygenase system of insect pests. Imidacloprid is a substance of the chloronicotinyl nitroguanidine group. It has a neurotoxicity in which affects the nicotinic acetylcholine receptors (naChrs) (Bodereau Dubois et al, 2012) [3]. Imidacloprid can be tranferred from contact and ingestion, and it is moderately toxic to mammals in the laboratory. Therefore, Imidacloprid is an alternative chemical to control the cockroaches. Boric acid is classified as a highly effective inorganic substance. The advantage of this acid is good water solubility and is mildly toxic at low concentrations to humans and mammals (Jiang *et al.*, 2021) [9]. The aims of this study are 1) to examine and compare the efficiency of some gel baits insecticidal products in the Thai markets that can affect mortality rates against two species of cockroaches: American cockroach (*P. americana*) and German cockroach (*B. germanica*) under laboratory conditions, and 2) to examine and compare the efficiency of

those gel baits products in the Thai markets that can affect attraction rates against those two species of cockroaches. These two cockroach species are commonly found in human residence as well as other places in Thailand.

Materials and Methods

Cockroaches rearing

Cockroaches (American cockroach (*P. Americana*) and German cockroach (*B. germanica*)) were given from Department of Medical Sciences, National Institute of Health, and collected from dark and damp places like drains. The cockroaches were reared in laboratory at King Mongkut's Institute of Technology Ladkrabang under laboratory conditions at temperature (27 ± 2 °C) and humidity (65 ± 5% RH). All specimens were provided with bread as food and pieces of cotton soaked with water as described by Durier and Rivault (2000) [6]. A 50 × 30 × 30 cm wooden frame with a glass upper side covered with muslin were used as rearing containers. Each container was provided with corrugated papers for shelter.

Gel baits tested

The four baits were tested including Acephate 3% w/w, Dichlorvos 1% w/w, Imidacloprid 2.5% w/w and Nano boric acid. Because only the active ingredient in the bait was known whereas the exact full content of these commercial baits formulations was not shown, it was not possible to evaluate their ingredients separately. For this reason, the gel baits were examined against cockroach in choice/no-choice method.

Experiments on the efficacy test

Efficacy tests were conducted according to a method of Wang *et al.* (2004) in the same conditions as rearing processes to determine the mortality rate caused by these chemicals. Glass boxes (50 × 30 × 30 cm) with upper side covered by perforated plastic sheet to prevent escaping of cockroaches were used in this study. Fifty adults from both male and female of *P. americana* and *B. germanica* cockroaches were treated in separated boxes (20 individual/box). Cockroaches were starved and acclimated in the boxes for 24 hours before bait was introduced to the box. To ensure that all added cockroaches would remain in the boxes rather than aggregation elsewhere, the egg carton was placed in the cockroach colony for at least 2 days which was a procedure that results in the deposition of aggregation pheromone on the egg carton from these cockroaches (Buczkowski *et al.*, 2001).

After the acclimation period (24 hours), two bioassays to test for mortality rate of cockroaches were done as follows: 1) choice assay, a gram of gel bait was placed on a glass slide and introduced to the box. Each box also received one gram of white bread for the cockroach as food. The control box was prepared only with white bread. The mortality rate of the tested cockroaches was recorded every day at 0, 5, 15, 30 min., and 1, 3, 6 12, 24 and 48 hours in total of 2 days. Three replicates were done for each gel bait product and for each sex. Cockroaches were considered dead if they could not escape when flipped over with a pair of forceps, and 2) no-choice assay: This assay was conducted as in the above choice assay but without adding the food in the tested boxes.

Experiments on the attraction test

Attraction or attractiveness of these chemicals to cockroaches was conducted according to the method of Anaclerio and Molinari (2012). Glass boxes (50 × 30 × 30 cm) with upper side covered by perforated plastic sheet to prevent cockroaches escaping were used to evaluate the attraction of the tested gel baits. Two shelters that made of egg carton were placed in two opposite corners inside each box, and cockroaches were left 24 hours in the box for starvation and adaptation before the bioassay was started and done. To verify the attraction of the gel bait, a drop (around 0.2 g) was placed on a glass cover slide and put in the middle of a sticky trap (a cardboard covered with rat glue) located in the middle position of the box. An empty sticky trap was used as a control in separated replicates since in each bioassay, only one sticky trap was put in the box. The catches assessment was done after 1, 2, 3, 4 and 5 days, and caught cockroaches were left inside the trap. Three replicates were carried out for each gel bait product and for each sex (20 individuals/box) in the same conditions as rearing method.

Statistical analysis

Data were analyzed by using one way ANOVA in SPSS program, the values of mean mortality percentage and their standard error (SE) were calculated.

Results and Discussion

The mortality rate of males and females of both American cockroach (*P. Americana*) and the German cockroach (*B. germanica*) were increased as the exposure time to gel baits was expanded. In total of two days after exposure of gel baits (0, 5, 15, 30 min., and 1, 3, 6 12, 24 and 48 hours), mortality rate was significantly the greatest for both sexes when exposed to Acephate 3% w/w (95%) whereas the mortality rate when applied to Dichlorvos 1% w/w was around 75%. The related results were obtained by Nasirian (2010) [16] who explained that mortality of German cockroach was 100% after 6 days of ingestion of fibronil. Hanii *et al.*, (2006) [8] reported that the reduction rates of German cockroaches by applying fipronil baits were 90.9%, 96.4% and 89.4% at Korean restaurants, Chinese restaurants, and beer hall kitchens, respectively, after 4 weeks of the treatment.

Both Acephate 3% w/w and Dichlorvos 1% w/w were highly effective against both American cockroach (*P. americana*) and the German cockroach (*B. germanica*), providing quick knockdown and killing actions after exposure to the gel baits insecticide treated, resulting in nearly 100% mortality. Toxicity comparison of the two insecticidal products tested against both American cockroach (*P. americana*) and the German cockroach (*B. germanica*) decreased in the order of Acephate 3% w/w and Dichlorvos 1% w/w, respectively. Table 1 and Table 2 show the efficacy trials (Toxicity and mortality rate) of two different bait products against adults of both American cockroach (*P. americana*), and the German cockroach (*B. germanica*) through two days of experiments, respectively.

In the attraction or attractiveness experiment, Imidacloprid 2.5% w/w had the attraction rates at 5.1±0.05 individuals per minute whereas Nano boric acid had the attraction rates at 3.07±0.12 individuals per minute which was the lowest level of attraction from this study. The daily percent trap catches of the tested gel baits showed some interesting results. All the products were significantly different from the control. The females were less attractive than males.

Nalyanya *et al.* (2001) [14] evaluated the attraction of several insecticide gel bait formulations contained boric acid to German cockroaches and indicated that nymphs were as responsive as males while females were less responsive. In some cases, for example, the *B. germanica* consumed baits consisting of an attractant by maximum of 97.17*%* more than the baits without the attractant as reported by Zhikuan *et al.*, (2008) [18]. Table 3 and Table 4 show the attraction rate of two different bait products to adults of both American cockroach (*P. americana*) and the German cockroach (*B. germanica*) during investigation period, respectively.

Table 1: The efficacy trials (Toxicity and mortality rate tests) of two different bait products against adults of the American cockroach (*P. americana*)

Products / minutes	*%* Mortality ± SE									
	0	5	15	30	60	180	360	720	1,440	2,880
Acephate 3% w/w	0	0.04± 2.06	0.15± 1.30	0.32± 2.95	0.56±1.33	0.78±3.77	1.59±1.48	3.26±0.51	5.41±0.73	6.37±4.42
Dichlorvos 1% w/w	0	0.02± 1.03	0.07±1.75	0.14±2.07	0.36±3.21	0.54±1.23	0.87±2.31	1.49±1.14	2.78±2.17	1.22±1.31

Table 2: The efficacy trials (Toxicity and mortality rate) of two different bait products against adults of the German cockroach (*B. germanica*)

Products / minutes	*%* Mortality ± SE									
	0	5	15	30	60	180	360	720	1,440	2,880
Acephate 3% w/w	0	0.37±1.24	0.63±2.35	1.11±1.67	2.26±3.12	4.04±1.63	6.29±2.11	7.81±1.24	8.70±3.47	9.43±1.25
Dichlorvos 1% w/w	0	0.19±2.11	0.35±1.13	0.87±1.79	1.68±2.64	2.96±3.18	4.31±1.25	5.77±2.43	7.12±1.32	8.72±2.84

Table 3: The attraction rate of two different bait products to adults of the American cockroach (*P. americana*)

Products / Day	% Trap catch ± SE				
	Day 1	Day 2	Day 3	Day 4	Day 5
Imidacloprid 2.5% w/w	3.36 ± 0.33	4.15 ± 1.24	5.61 ± 2.16	6.37 ± 1.13	7.14 ± 1.87
Nano boric acid	2.11 ± 1.12	3.42 ± 0.13	4.22 ± 1.83	5.21 ± 1.75	6.45 ± 2.51

Table 4: The attraction rate of two different bait products to adults of the German cockroach (*B. germanica*)

Products / Day	% Trap catch ± SE				
	Day 1	Day 2	Day 3	Day 4	Day 5
Imidacloprid 2.5% w/w	8.34 ± 1.12	11.27 ± 2.32	14.42 ± 1.67	17.11 ± 2.31	18.25 ± 0.21
Nano boric acid	5.21 ± 2.31	7.65 ± 1.13	10.13 ± 2.56	13.32 ± 1.36	15.53 ± 2.24

Conclusion

From the results, we concluded that both American cockroach (*P. americana*) and German cockroaches (*B. germanica*) had the mortality rate of at 95% when exposed to Acephate 3% w/w whereas both American cockroach and German cockroach had the mortality rate at 75% only when applied to Dichlorvos 1% w/w. In the attraction experiment, Imidacloprid 2.5% w/w had the average attraction rates at 5.1±0.05 individuals per day while Nano boric acid had the average attraction rates at 3.07±0.12 individuals per day only. These products were recommended to use rather than other commercial gel baits in Thailand.

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