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Brief communication (Original)

Comparison of slow and fast action gel baits for pest management of *Blattella germanica* (German cockroach) infestation in housing

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Background: Gel baits are important for integrated pest management (IPM). The relative efficacy of various baits is unknown.
Objectives: To evaluate the efficacy of different gel belts (hydramethylnon 2%, fipronil 0.05%, and imidacloprid 2.15%) for control of *Blattella germanica* (German cockroach) infestation.
Methods: All the tested (field) strains were collected from housing in Yasuj city, Iran. Ten German cockroaches for each developmental stage were placed in separate labeled glass rearing jars of the same size. Mortality was observed at 12 h intervals after exposure to baits. Each study was conducted in triplicate.
Results: All gel baits produced 100% mortality of cockroaches within 1 to 5 days. However, imidacloprid killed cockroaches more rapidly (LT_{50} = 13.3 h) than fipronil (LT_{50} = 32.5 h) or hydramethylnon (LT_{50} = 61.6 h). The results showed rapid, quick, and slow action for the three baits respectively. Comparison between the baits showed that the slow action bait is more compatible with IPM, being the most effective in 3 or more days; increased potential for secondary mortality through horizontal transmission of lethal dose and also via residue; decreased risk of food contamination by dead cockroaches; will decrease the chance of behavioral resistance, and it had higher feeding stimulation potential than the others.
Conclusions: Hydramethylnon is preferred for IPM. Fipronil is a plausible alternative.

Keywords: Cockroach infestation, fast action bait, IPM, slow action bait

Integrated pest management (IPM), is defined as the selection, integration and implementation of pest control based on predicted economic, ecological and sociological consequences. Application of insecticidal baits in IPM can be an effective approach for controlling *Blattella germanica* (German cockroach). The three most popular gel baits that have been introduced for IPM of the German cockroach are hydramethylnon, fipronil and imidacloprid [1-4].

Fipronil, a phenylpyrazole-type insecticide, kills insects by interacting agonistically with γ-aminobutyric acid-gated chloride channels [5]. Fipronil slowly degrades in soil and water, with a half-life ranging between 36 h and 7.3 mo. The toxicity of fipronil to laboratory mammals by oral exposure is moderate (LD_{50} = 97 mg/kg for rats, LD_{50} = 91 mg/kg for mice) [6]. Fipronil is classified as a quick action bait by Stejskal et al. [7].

Imidacloprid is a neonicotinoid in the chloronicotinyl nitroguanidine class of insecticides with a high selective toxicity to insects [8, 9]. Imidacloprid acts on several types of postsynaptic nicotinic acetylcholine receptors in the nervous system [10]. The toxicity of imidacloprid to laboratory mammals is moderate by oral exposure (LD_{50} = 4000 mg/kg for rats, LD_{50} = 131 mg/kg for mice). Imidacloprid has low vapor pressure with a half-life of 30 days in water and 27 days anaerobically in soil [9]. Imidacloprid is classified as a rapid action bait by Stejskal et al. [7] and as toxic to all developmental stages of the German cockroach by Appel and Tanley [9].

Hydramethylnon is an amidino hydrazone type pesticide that acts by disrupting energy production (inhibiting the formation of ATP) at the cellular level. Hydramethylnon has low mammalian toxicity with a half-life more than one year (from 375–391 days) in aerobic soil and is stable at high temperature [11].

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This bait is classified as a slow action bait by Stejskal et al. [7]. Toxicity of hydramethylnon gel bait against the German cockroach was reported by Appel [12], Khadri and Lee [13], and Sulaiman et al. [14].

The purpose of this study was to determine the comparative toxicity of the three toxicants on the German cockroach.

Materials and methods

All the tested German cockroaches (field strain) were collected from dormitories (in the Yasuj University of Medical Sciences) in Yasuj city, Iran. Cockroaches were collected using jar traps, which were installed overnight. They were one liter glass jars each containing a slice of bread and beer and with inner upper surface of the jar coated with petroleum jelly to prevent escape. The study was conducted in the medical entomology laboratory of the Yasuj University of Medical Science.

Adult males and nongravid females and small nymphs (2–4th instar, 3.5–10 mm in length) and large nymphs (5–6th instar, 10.5–14 mm in length) were used in the toxicity tests. Ten German cockroaches at each developmental stage were placed in separately labeled glass rearing jars of the same size (one liter). The jars were provided with a mouse pellet as food (1g), water (a moistened cotton wick) and a 140 cm^2 cardboard cylinder as harborage [9]. Mortality was observed at 12 h intervals for 5 days (until all cockroaches were dead) at the same temperature (25°C–28°C), humidity (%50 ± 5 RH) and photoperiod (12:12 h, light: dark). The upper inside surface of the jars was lightly greased with petroleum jelly to prevent the cockroach from escaping. Additionally, muslin cloth covers were secured with rubber bands over the opening to provide air. There were three replicates (jars) for each study, i.e. (stages of the German cockroaches). Before the test was started, cockroaches were left to habituate to test conditions for one day [15].

Three most popular gel baits that were introduced for the IPM programme were evaluated for their toxicity against the German cockroach. Chemicals used were hydramethylnon gel bait 2% (commercialized as Siege, BASF, Shah Alam, Malaysia), imidacloprid gel bait 2.15% (Bayer, Leverkusen, Germany), and fipronil gel bait 0.05%, (commercialized as Goliath, Rhone-Poulenc Rhodia, Lyon, France). Before treatment, the German cockroaches were fasted for 24 h to increase their hunger level and thereby optimizing their response during the test [15]. Initially after fasting they exposed to food and then 0.5 g of each bait was placed in a plastic boat (plug) in treatment jars [9, 16, 17]. The two kinds of foods (mouse pellet and bait) were introduced allow the cockroaches to make a choice and more accurately reflect the situation in the "field". Control treatments contained only water, mouse pellet, and cardboard. For each developmental stage, each replicate comprised 10 cockroaches. There were three replicates (jars) for each stage totalling 120 cockroaches in 12 colony jars for the three gel treatments and an equal number of cockroaches for each control, i.e. hydramethylnon, fipronil, and imidacloprid bait treatment.

Mortality data were analyzed by probit analysis, using SPSS software version 15.0 (SPSS, Chicago, IL, USA) to determine LT_{50}s and LT_{90}s of treatments and subsequent slopes of probit regressions. Normality of data and homogeneity of variances was detected by using exploratory and Levine's test (SPSS). Data was transformed to obtain a normal distribution and homogeneity of variance. To determine significant differences between means, a Mann–Whitney *U* test or *t* test, and ANOVA or Kruskal–Wallis test were employed.

Results

All gel baits produced 100% mortality of German cockroaches within 1–5 days. There was no mortality for the controls. The LT_{50} values for various developmental stages of the German cockroach exposed to imidacloprid, fipronil, and hydramethylnon gel baits ranged from 12.5 to 14.5 h, 31.2 to 35 h and 57 to 64.8 h respectively (**Table 1**). The LT_{90}s and LT_{50}s for the baited cockroaches showed significant differences ($P < 0.05$) among LT_{50}s (or LT_{90}s) of the three gel bait treatments. However, there was no significant difference among the LT_{50} values for the four German cockroach stages when exposed to hydramethylnon (Chi-square: 4.39, $P = 0.11$). Similar results were observed for the imidacloprid and fipronil gel bait treatments. Additionally, **Figure 1** shows the all developmental stages of the German cockroaches died (100%) after 2 days of treatment for imidacloprid, 3 days for fipronil treatment, and 5 days for hydramethylnon treatment, and mortality was 100% for all treatment by the fifth day.

Table 1. Toxicity of the three gel baits to various developmental stages of the German cockroach

Baits	Developmental Stages	n	Slope ± SE	LT_{50} (95%CI)*	LT_{90} (95%CI)*
Imidacloprid	Male	30	0.33 ± 0.44	12.5 (10.3–14.4)	19.3 (16.3–23.3)
	Female	30	0.12 ± 0.02	12.7 (9.5–15.3)	25.2 (21.1–33.1)
	Large	30	0.14 ± 0.02	13.7 (11–15.9)	23.9 (20.3–31.1)
	Small	30	0.15 ± 0.02	14.5 (12.1–16.7)	24.2 (20.7–31.1)
Fipronil	Male	30	0.1 ± 0.01	35 (31.9–37.9)	49.7 (45.3–56.7)
	Female	30	0.1 ± 0.01	32.3(29.2–35.2)	47.4 (42.9–54.8)
	Large	30	0.13 ± 0.02	31.2(28.4–33.8)	43 (39.1–49.8)
	Small	30	0.11 ± 0.02	31.4 (28.6–34.2)	44.4 (40.3–51.4)
Hydramethylnon	Male	30	0.17 ± 0.06	63.9 (60.6–67.1)	79.6 (75.2–86.4)
	Female	30	0.07 ± 0.01	64.8 (60.9–68.5)	89 (83.2–97.4)
	Large	30	0.05 ± 0.01	57 (52.5–61.3)	91.4 (83.8–102)
	Small	30	0.06 ± 0.01	60.8 (43.3–77.3)	91.2 (72.6–168.1)

*hours; means of LT_{50}s and LT_{90}s among the three baits were significantly different at $P < 0.05$ ($F = 239.11$ and 655.37 respectively)

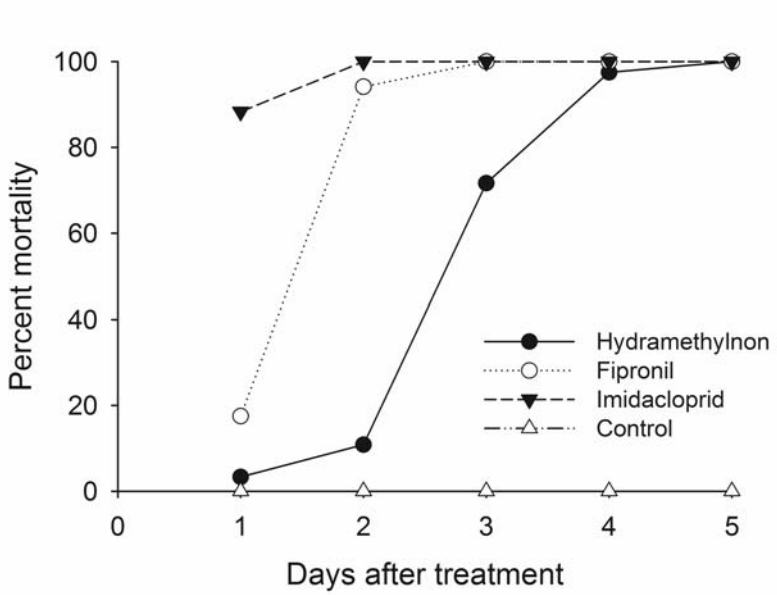

Figure 1. Percentage mortality of treated and untreated (control) German cockroaches by the three gel baits within the 5 day treatment period. Error bars represent standard deviation.

Discussion

Our findings are consistent those of Durier and Rivault [18] who reported cockroach age did not affect performance in tests for hydramethylnon and fipronil. However, in the present study the LT_{50} for large nymph stage of the German cockroach treated with hydramethylnon showed the lowest value ($P > 0.05$). The average LT_{50} (or LT_{90}) values for various stages of the German cockroach exposed to hydramethylnon (LT_{50} = 61.6 and LT_{90} = 87.8 h) exceeded that of fipronil (LT_{50} = 32.5 and LT_{90} = 46.1h) and imidacloprid (LT_{50} = 13.3 and LT_{90} = 23.1 h) baited cockroaches respectively. In other words, imidacloprid killed cockroaches more rapidly than fipronil and hydramethylnon.

Delayed action of the hydramethylnon gel bait (no mortality) was observed within 24 to 48 h. These results confirmed the different modes of action for these three baits as was substantiated and nominated as rapid action bait (such as imidacloprid), quick action

bait (such as fipronil), and slow action bait (such as hydramethylnon) by Stejskal et al. [7]. This finding is also consistent with those reported by Lee [19] and Durier and Rivault [18] who reported a faster effect of fipronil than hydramethylnon gel bait against the German cockroaches. A similar result was reported by Sulaiman et al. [14] for the American cockroach, *Periplaneta americana*. Appel [12] reported a mean lethal time LT_{50} of 57.6 h for the German cockroaches exposed to 25.4% hydramethylnon bait (Maxforce). Appel and Tanley [9] reported a mean lethal time LT_{50} of 9–37 h for the German cockroaches exposed to 2.15% imidacloprid bait. Hydramethylnon is recently introduced while fipronil and imidacloprid are relatively new insecticides, which are currently not affected by resistance compared with insecticides previously used for German cockroach control in Iran [20]. Comparison between these three effective baits for control of the German cockroach showed that slow action bait, such as that by hydramethylnon is more compatible with IPM purpose, because: (1) being most effective in 3–14 days (or more) after application [3, 7, 21]; (2) increased potential for secondary mortality through horizontal transmission of lethal dose by coprophagous and cannibalistic activities [19, 22]; (3) increased potential for secondary mortality in the absence of cannibalism and necrophagy via residue of hydramethylnon (Buczkowski et al. [23] suggesting that hydramethylnon is highly effective in these assays in comparison with the other baits such as fipronil); (4) decreased risk of food contamination by dead cockroaches [7]; and finally (5) because it works slowly, cockroaches will not generally learn to avoid them, and thus will decrease the chance of behavioral avoidance or resistance [24]. Additionally, Durier and Revault [25] showed hydramethylnon gel had higher feeding stimulation potential than fipronil gel (and abamectin gel). Appel [12] reported that toxicity of hydramethylnon bait increased with bait age. Effectiveness of hydramethylnon gel bait (through field efficacy) in an IPM program and in comparison with insecticidal spraying of German cockroach were substantiated by Shahraki et al. [26]. However, in field efficacy tests to determine effects on bait performance against German cockroach, sanitation (as a tactic in an IPM approach) showed an important role [27, 28]. Therefore, among the three gel baits evaluated with 100% mortality rate, hydramethylnon is preferable for IPM, although for further application and to avoid resistance after a few usage, fipronil is a plausible alternative, suitable to treatment in an IPM approach.

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Conflict of interest statement

The authors declare that there is no conflict of interests regarding the publication of this article.

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