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FACTORS AFFECTING COPROPHAGY AND NECROPHAGY BY THE GERMAN COCKROACH (DICTYOPTERA: BLATTELLIDAE)

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Abstract Modern bait formulations have been used successfully to control infestations of the German cockroach, *Blattella germanica* (L.) since the mid 1980s. Because of the slow-acting insecticides used in most bait formulations, unmetabolized insecticide may be excreted in the feces and oral secretions, and remain in the body of dead cockroaches. Coprophagy and necrophagy are reportedly important means of distributing insecticide into infested locations and inducing "secondary kill". Our results question the significance of coprophagy and necrophagy as important means of insecticide transmission in typical German cockroach infestations. When either adult males or 1st-3rd instar nymphs were presented feces from adult male cockroaches killed by exposure to a variety of toxic baits or the dead cockroaches, there was <25% mortality after 14 d. Mortality declined even further when the cockroaches were provided a choice between food and either toxic feces or a dead cockroach. In many replicates, cockroaches would not feed at all on cadavers or feces even when starved for 24-72 h. In behavioral assays, cockroaches preferred virtually all alternative foods to cadavers or feces. Although there may be significant differences in food preferences and aversions among German cockroach strains, our data indicate that coprophagy and necrophagy are the last resort of starving cockroaches. These results also point out the importance of sanitation (removal of food sources) for successful management of German cockroach infestations.
Key Words Bioassay, secondary kill, food preference, sanitation

INTRODUCTION

Modern bait formulations have been used successfully to control infestations of the German cockroach, *Blattella germanica* (L.), since the mid 1980s. Because of the slow-acting insecticides used in most bait formulations, unmetabolized insecticide may be excreted in feces and remain in the body of dead cockroaches where may be available to other individuals. Coprophagy (consumption of feces) and necrophagy (the consumption of cadavers) may be important means of distributing insecticide into infested locations resulting in "secondary kill" of individuals that did not directly consume the toxic bait (e.g., Silverman et al., 1991; Buczkowski et al., 2001).

The purpose of this study was to evaluate the potential importance of coprophagy and necrophagy to "secondary kill". In several experiments, we presented cockroaches with either contaminated feces or bait-killed cadavers alone, or in the presence of competitive food and determined mortality.

MATERIALS AND METHODS

Insects and Baits

Adult male and 1st-3rd instar insecticide-susceptible German cockroaches (American Cyanamid, Clifton, NJ) were used in the experiments. Cockroaches were obtained from colonies reared in 200 liter plastic trash cans provided with cardboard harborage, dry dog food (Purina Dog Chow®, Ralston-Purina, St. Louis, MO), and water ad libitum. Cockroaches were reared at 27 ± 2ºC, 80 ± 10% RH, and a photoperiod of 12:12 (L:D) h. Bait formulations tested contained one of seven different insecticides (Table 1).

Table 1. Cockroach bait products used in the coprophagy and necrophagy tests.

Brand	Manufacturer	Active ingredient
Advion gel bait	DuPont	Indoxacarb, 0.6%
Avert gel bait	Whitmire Micro-Gen	Abamectin B1, 0.011%
MaxForce FC	Maxforce Insect Control Systems	Fipronil, 0.01%
MaxForce	Maxforce Insect Control Systems	Hydramethylnon, 2.15%
PreEmpt	Bayer	Imidacloprid, 2.15%
Pro-Joe-S	Blue Diamond	Boric acid, 15%
Experimental gel	Whitmire Micro-Gen	Dinotefuran, 0.5%

Toxicity and Preparation of Contaminated Cadavers and Feces.
Groups of adult male and 1st-3rd instar cockroaches were starved for 24 h then exposed to 0.5 g deposits of bait. Water was continually provided. Cockroaches were held in 0.95-liter glass jars at 25-28°C and 50-65% RH. Mortality was recorded daily and the dead cockroaches were removed, frozen, and used for the necrophagy experiments below. Groups of adult male cockroaches were held in 15 cm diameter plastic Petri dishes with bait, water, and a small harborage. Mortality was recorded daily and the dead cockroaches were removed and the feces-contaminated Petri dishes were used in the coprophagy experiments below.

Coprophagy Experiments
Groups of 20 1st-3rd instar insecticide-susceptible German cockroaches were confined in previously contaminated 15 cm diameter plastic Petri dishes. Any residues from the baits or cockroach body parts were removed prior to the experiments. Water and a piece of dry dog food were included in the Petri dish. Mortality was recorded daily for 14 d. There were 6 replicate jars for each bait treatment.

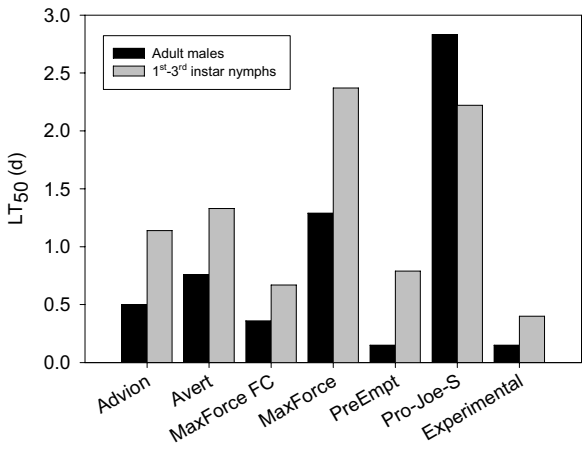

Figure 1. Toxicity of several insecticidal baits to German cockroaches.

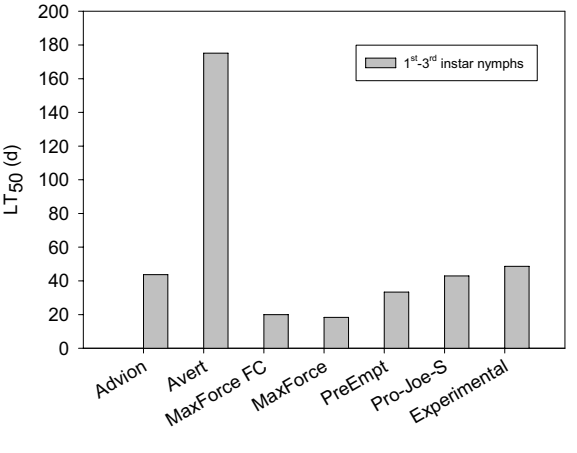

Figure 2. Toxicity of adult male German cockroach feces to 1st-3rd instar nymphs.

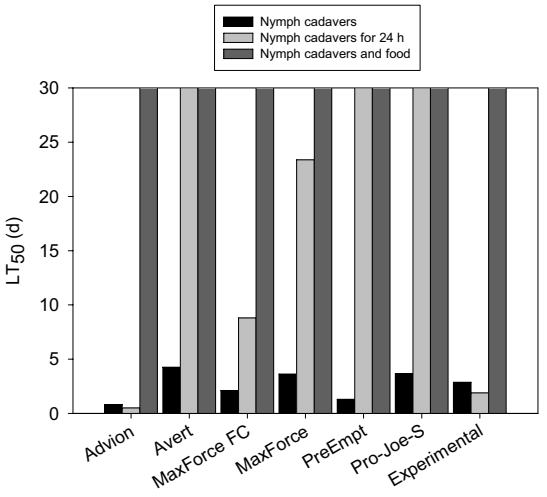

Figure 3. Toxicity of nymphal cadavers to adult male German cockroaches.

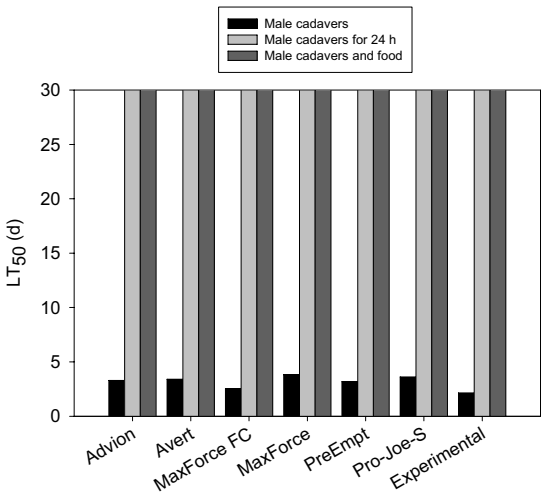

Figure 4. Toxicity of adult male cadavers to adult male German cockroaches.

Necrophagy Experiments

Groups of adult male cockroaches, confined in plastic Petri dishes, starved for 24 h, then provided one of the following food treatments: ten 1st-3rd instar or adult male cadavers (available continuously), ten 1st-3rd instar or adult male cadavers for 24 h, then the cadavers were removed and replaced with dry dog food, and ten 1st-3rd instar or adult male cadavers and dry dog food were both available continuously. Cadavers were replaced daily as necessary. There were 6 replicate jars for each stage, bait, and treatment combination.

Data Analysis

Mortality was analyzed using probit analysis for correlated data (Throne et al., 1995) because multiple observations were taken on the same individuals.

RESULTS

All bait formulations were toxic to adult male and 1st-3rd instar German cockroaches (Fig. 1). Interestingly, the LT_{50} values for all baits, except the boric acid-based Pro-Joe-S, were greater for 1st-3rd instar nymphs. This result may be due to coprophagy during starvation and less consumption of bait, greater aggregation and less consumption of bait, or increased levels of detoxifying enzymes in the rapidly developing nymphs.

There was no control mortality of 1st-3rd instar nymphs in the coprophagy experiments. There was significant mortality of nymphs exposed to the feces of adult males who had fed on insecticidal baits (Fig. 2). LT_{50} values for nymphs exposed to contaminated feces ranged from 18.3 d to 175.2 d for MaxForce gel containing 2.15% hydramethylnon and Avert gel containing 0.011% Abamectin B1, respectively.

Adult male and nymphal German cockroaches were killed after consumption of bait-killed adults or nymphs. Clearly the cadavers contained sufficient insecticide to cause mortality of additional cockroaches (Figs. 3-4). However, when adult male cockroaches were presented with a choice of an additional 24 h of starvation or consumption of cadavers, most did not exhibit necrophagy. Nymphal cadavers were more readily consumed than adult male cadavers; with any alternative food, the cadavers from only four bait formulations resulted in LT_{50} values <30 d (Fig. 3). When adult males were given the choice between cadavers and food, there was virtually no consumption of cadavers resulting in LT_{50} values >30 d for all bait formulations (Figs. 3, 4).

DISCUSSION

Our results question the significance of coprophagy and necrophagy important means of insecticide transmission in typical German cockroach infestations. Although adult feces are clearly toxic to nymphs, the

LT_{50} values are >18 d and in one case >175 d. Adult male feces may not be as attractive as female or nymphal feces, but there is little evidence that cockroaches prefer feces to normal food. In typical infestations, either the cockroach populations are relatively small and there are few fecal deposits, or the infestation is very large and the environment is replete with feces (and cadavers). In any event, cockroach debris should be removed since it is highly allergenic to sensitive individuals.

When adult male cockroaches were presented cadavers of adult males or 1st-3rd instar nymphs killed by exposure to a variety of toxic baits there was generally <25% mortality after 14 d and LT_{50} values >30 d. Mortality declined even further when the cockroaches were provided a choice between a cadaver and food. In behavioral assays, cockroaches preferred nearly all alternative foods to cadavers (containing insecticidal or not). Although there may be differences in food preferences and aversions among German cockroach strains, our data demonstrate that necrophagy is the last resort of starving cockroaches.

Our results further emphasize the importance of sanitation (especially removal of food sources) for successful management of German cockroach infestations.

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