

RESIDUAL EFFICACY OF BLATTICIDES APPLIED TO  
SURFACES CONTAMINATED WITH GERMAN COCKROACH  
(DICTYOPTERA: BLATTELLIDAE) FECES

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ABSTRACT

Crack-and-crevice treatments were simulated in the presence and absence of German cockroach [*Blattella germanica* (L.)] feces to evaluate its effect on insecticide efficacy toward the German cockroach. The  $LT_{50}$  of German cockroaches exposed to 0.39  $\mu\text{g}$  of cypermethrin/ $\text{cm}^2$  (Demon EC formulation) on glass Mason jars was 26 min. The  $LT_{50}$  increased 2.5- and 4.5-fold when Demon EC was mixed with 123 and 184 mg of cockroach feces, respectively. The presence of German cockroach feces increased the  $LT_{50}$  2.5-fold in Dursban EC (chlorpyrifos) and 1.2-fold in Baygon EC (propoxur). Longevity experiments with 3  $\lambda$ -cyhalothrin formulations in the presence of German cockroach feces resulted in significant decreases in insecticide efficacy. Feces reduced the performance of Commodore WP ( $\lambda$ -cyhalothrin) by 12.5, 35, 55, and 97.5% on days 0, 10, 20, and 30, respectively. Initial reductions in efficacy were observed for the Demand CS ( $\lambda$ -cyhalothrin) and Karate ( $\lambda$ -cyhalothrin) formulations when in the presence of German cockroach feces.

Key Words: *Blattella germanica*, feces, insecticide efficacy, formulation

RESUMEN

Tratamientos de grietas y hendiduras fueron simulados en la presencia y ausencia de heces fecales de la cucaracha alemana [*Blattella germanica* (L.)] para evaluar su efecto en eficacia del insecticida hacia la cucaracha alemana. El  $LT_{50}$  de cucarachas alemanas expuestas a 0,39  $\mu\text{g}$  de cypermethrin/ $\text{cm}^2$  (formulación Demon EC) en jarras de vidrio Masón fue 26 minutos. El  $LT_{50}$  incrementó 2,5 y 4,5 veces cuando se mezcló Demon EC con 123 y 184 mg de heces fecales de cucaracha, respectivamente. La presencia de heces fecales de la cucaracha alemana incremento el  $LT_{50}$  2,5 veces en Dursban EC (chlorpyrifos) y 1,2 veces en Baygon EC (propoxur). Experimentos de longevidad con 3 formulaciones  $\lambda$ -cyhalothrin en presencia de heces fecales de cucaracha alemana resulto en disminuciones significativas en eficacia del insecticida. Las heces fecales redujeron el desempeño de Commodore WP ( $\lambda$ -cyhalothrin) por 12,5, 35, 55, y 97,5% en los días 0, 10, 20, y 30, respectivamente. Reducciones iniciales en eficacia fueron observadas en formulaciones de Demand CS ( $\lambda$ -cyhalothrin) y Karate ( $\lambda$ -cyhalothrin) cuando en presencia de heces fecales de la cucaracha alemana.

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Recent public concern over the environmental and health impacts of pesticides has discouraged the traditional use of broad spray treatments for control of German cockroach, *Blattella germanica* (L.). Although residual insecticide treatments are still

used against German cockroaches, the method of application is typically confined to suspected cockroach aggregation sites or harborages. This method of insecticide application is commonly known as crack-and-crevice treatment. Crack-and-crevice insecticide placement reduces the amount of toxicant required for control (Bennett et al. 1988) and minimizes insecticide exposure risks to humans and pets.

German cockroaches are gregarious (Roth & Willis 1960) often spending up to 75% of their lifetime at rest in harborages (Cornwell 1968). Within these harborages, feces accumulate and may affect the efficacy of crack-and-crevice insecticide applications. Surface type (Cornwell 1972), organic matter (Niemczyk & Krueger 1987, Kamm & Montgomery 1990), and oils (Newton & Coombes 1990) influence the performance of various residual insecticide formulations.

We simulated crack-and-crevice treatments in the presence and absence of German cockroach feces for the purpose of evaluating the effect of feces on insecticide efficacy.

## MATERIALS AND METHODS

### Cockroaches and Feces

Adult males (1-2 wk old) of the insecticide susceptible Orlando strain of German cockroach (Koehler & Patterson 1986) were used for all bioassays. The cockroaches were reared as described by Koehler et al. (1994).

German cockroach feces were collected from rearing containers of final instar cockroaches. Feces were separated from cast skins and other debris with a steel sieve (0.71-mm<sup>2</sup> openings) followed by fine mesh steel sieve (0.48-mm<sup>2</sup> openings) for use in subsequent experiments.

### Insecticides

Emulsifiable concentrate (EC) formulations of cypermethrin (Demon EC, 25.3% [AI]; Zeneca, Wilmington, DE.), chlorpyrifos (Dursban 2E, 24.1% [AI]; Dow Agro-Sciences, Indianapolis, IN),  $\lambda$ -cyhalothrin (Karate, 10% [AI] Zeneca), and propoxur (Baygon 1.5 EC, 14.7% [AI], Bayer, Kansas City, MO) were used in efficacy experiments. Additionally, the wettable powder (WP) and microencapsulated formulations of  $\lambda$ -cyhalothrin (Commodore WP 10% [AI] and Demand CS 9.7% [AI], respectively) were included in the study. All formulations were diluted in water to form an emulsion or suspension and pipetted into jars for tests.

### Bioassays

Time-mortality relationships (Cochran 1997) were first established for formulated cypermethrin (Demon EC) in the presence of increasing quantities of cockroach feces. Cockroach feces (0, 0.24, 0.48, or 0.72 mg per cm<sup>2</sup>) were added to Mason jars (473 ml, surface area = 256 cm<sup>2</sup>; Ball Corp., Muncie, IN). The Demon EC formulation of cypermethrin was prepared at a rate of 0.1 mg[AI]/ml by adding 40  $\mu$ l of the EC to 99.96 ml of water. One ml of this solution was pipetted into each jar. An additional 3 ml of water also was added to each jar to facilitate even coating with the feces-insecticide mixture. The jars were placed on a roller on their sides and rotated continuously with a gentle stream of compressed air directed into each jar. After the jars were dry (typically 4 h) the upper 2 cm of the interior was coated with a petroleum jelly:mineral oil mixture

(3:2) to prevent cockroaches from escaping. Ten adult male cockroaches of the Orlando strain were placed into each jar individually with featherweight forceps. The cockroaches were not anesthetized with CO<sub>2</sub>. The jars were placed into an environmental chamber and held at 24.9 ± 0.4°C and 69.6 ± 3.9% RH. Control jars were treated with water and feces only. A repeated measures method was used to assess lethal time values. Cockroaches were monitored every 5 min and the number dead recorded until 80% of the cockroaches in the jar were killed. Cockroaches were considered dead or moribund if unable to right themselves within 15 sec after being flipped onto their dorsum. Treatment mortality was corrected for control mortality with Abbott's formula (1925). The entire experiment was replicated 3 times. Mortality was analyzed with the Probit procedure (SAS Institute 1988). Significant differences were determined by nonoverlap of 95% confidence intervals.

The effect of feces on lethal time was compared among EC formulations of chlorpyrifos, cypermethrin, and propoxur. Dursban 2E, Baygon 1.5 EC and Demon EC were prepared in water at 3, 11, and 0.1 mg[AI]/ml, respectively. Mason jars were treated with 0.72 mg of feces/cm<sup>2</sup> and 1 ml of formulated insecticide as described previously. Additional water (3 ml) was added and the jars were rolled until dry. Cockroaches were added to each jar, mortality recorded, and data analyzed as described previously. The experiment was repeated three times. Data were analyzed by the Probit procedure with mortality as dependent variable (SAS 1988).

The last part of the study was to determine the effect of feces on the residual performance of 3 different formulations of λ-cyhalothrin. The wettable powder (Commodore WP), capsulated suspension (Demand CS) and emulsifiable concentrate (Karate) formulations were diluted in water at 0.1 mg[AI]/ml and 1 ml was applied to the inner walls of the jars. Each insecticide formulation was added to 2 jars, one containing 0.72 mg of feces/cm<sup>2</sup> and one not treated with feces. Ten adult male cockroaches were placed in each jar. After a 1-min exposure to the treated glass surface the cockroaches were anesthetized with CO<sub>2</sub> (15 sec), placed in an untreated glass Petri dish, and subsequently placed in another untreated plastic Petri dish (100 by 15 mm). Any feces deposited with the insects was returned to its respective jar. Cockroaches were held in an environmental chamber at 24.9 ± 0.4°C and 69.6 ± 3.9% RH. Mortality was assessed 24 h later. Jars were stored in the dark at room temperature (approximately 24°C). The bioassay was repeated at 10, 20, and 30 d after treatment by using the same jars. The experiment was replicated 5 times. Control jars were treated with water and feces. Mortality in the presence and absence of feces was compared by Student's t-test for each time period and formulation.

## RESULTS

The LT<sub>50</sub> of Orlando cockroaches exposed to glass Mason jars treated with 0.39 µg[AI]/cm<sup>2</sup> of Demon EC was 26 min (Table 1). This value was not significantly different from jars treated with Demon EC and 0.24 mg/cm<sup>2</sup> of German cockroach feces. However, the LT<sub>50</sub> increased 2.5- and 4.5-fold when Demon EC was mixed with 0.48 and 0.72 mg of feces/cm<sup>2</sup>, respectively. No mortality was observed in control jars devoid of insecticide but containing feces.

Among the 3 insecticide classes used in this study, cockroach feces had the greatest impact on the efficacy of cypermethrin (Table 2). The inhibition ratio (IR = LT<sub>50</sub> feces contaminated jar/LT<sub>50</sub> clean jar) for cypermethrin was 4.4-fold. The presence of German cockroach feces increased the time to mortality 2.5-fold in Dursban 2E (chlorpyrifos) and had a small, yet statistically significant (based on nonoverlap of 95% confidence intervals), effect on the toxicity of Baygon 1.5 EC (propoxur).

TABLE 1. THE  $LT_{50}$  VALUES (MIN) FOR ADULT MALE SUSCEPTIBLE COCKROACHES EXPOSED TO A DEMON EC (CYPERMETHRIN) TREATED MASON JAR ( $0.39 \text{ G/CM}^2$ ) IN THE PRESENCE OF INCREASING QUANTITIES OF GERMAN COCKROACH FECES.

Feces ( $\text{mg/cm}^2$ )	Obs <sup>a</sup>	Slope $\pm$ SE	$LT_{50}$ (95% CI)	$\chi^2$	IR <sup>b</sup>
0	420	$1.67 \pm 0.20$	25.55 (21.22-32.16)	1.98	1.00
0.24	400	$1.15 \pm 0.27$	20.63 (10.24-28.23)	8.65	0.81
0.48	400	$1.31 \pm 0.27$	63.77 (50.79-92.24)	9.96	2.50
0.72	810	$1.50 \pm 0.22$	115.59 (98.18-166.65)	1.09	4.52

<sup>a</sup>Total number of observations recorded until 80% mortality was achieved (repeated measure).

<sup>b</sup>IR = inhibition ratio ( $LT_{50}$  contaminated surface/ $LT_{50}$  clean surface).

Residual activity of various  $\lambda$ -cyhalothrin formulations in the presence and absence of German cockroach feces is illustrated in Figure 1. Mortality was reduced significantly among all formulations in the presence of feces. Feces reduced the performance of the WP by 12.5, 35, 55, and 97.5% on days 0, 10, 20, and 30, respectively (Fig. 1A). Initial reductions in efficacy were severe for the Demand CS and Karate formulations (Fig. 1B, C). Although Demand CS was effective on clean glass throughout the study, feces nearly eliminated its ability to kill cockroaches. Mortality on the Karate-treated surface declined sharply in the absence of feces, and no significant differences were observed between treatments with and without feces at 10, 20, and 30 d.

## DISCUSSION

Cracks and crevices in furniture, kitchen equipment, wall voids, and elsewhere in structures are primary harborage sites for the German cockroach (Cornwell 1968). These harborage sites often become heavily littered with cockroach feces (Stejskal 1997). Treatment of these areas with residual insecticides is a recommended method for cockroach control in food-handling establishments (Rust 1986, Bennett et al. 1988). Unfortunately, based on our data, fecal deposits found in these areas may significantly reduce the efficacy of some insecticides.

Decreased insecticide efficacy in the presence of German cockroach feces was anticipated based on results of previous reports. For example, organic matter in soil reduce insecticide toxicity by acting as an adsorbent (Hamaker & Thompson 1972). Similarly, activated carbon has been used to protect grass seed from herbicides (Lee 1973). German cockroach control failures in kitchens also have been associated with insecticide affinity to cooking oils (Ree 1980, Schal 1988, Rust & Reiersen 1988). In addition to reducing insecticide efficacy by adsorption, microbial degradation also may affect insecticide efficacy. Feces may contain microbes that could have the capacity to metabolize the insecticide. However, preliminary experiments with autoclaved feces resulted in comparable decreases in insecticide efficacy indicating that microbial degradation was not likely to be the mechanism responsible (C. Strong, unpublished data).

Among the EC formulations of 3 insecticide classes evaluated in this study, cockroach feces were most detrimental to the performance of cypermethrin, Demon EC (Table 2). Cypermethrin-treated jars containing feces ( $0.72 \text{ mg/cm}^2$ ) required 4.5-fold more time to kill cockroaches than insecticide in clean jars. Chlorpyrifos, Dursban 2E, toxicity also was significantly reduced (2.5-fold) by the presence of feces. The toxicity

TABLE 2. THE  $LT_{50}$  VALUES (MIN) FOR ADULT MALE SUSCEPTIBLE COCKROACHES EXPOSED TO AN INSECTICIDE FORMULATION IN THE PRESENCE OR ABSENCE OF GERMAN COCKROACH FECES (0.72 MG/CM<sup>2</sup>).

Treatment <sup>a</sup>	Surface	Obs <sup>b</sup>	Slope $\pm$ SE	$LT_{50}$ (95% CI)	$\chi^2$	IR <sup>c</sup>
Cypermethrin	clean	420	1.67 $\pm$ 0.20	25.55 (21.22-32.16)	1.98	1.00
Cypermethrin	feces	1080	1.75 $\pm$ 0.11	113.35 (105.03-123.28)	14.54	4.44
Chlorpyrifos	clean	600	15.24 $\pm$ 1.08	47.12 (46.28-47.98)	3.86	1.00
Chlorpyrifos	feces	810	13.22 $\pm$ 0.83	117.21 (114.82-119.48)	2.65	2.49
Propoxur	clean	500	11.00 $\pm$ 0.83	23.30 (22.63-23.97)	5.23	1.00
Propoxur	feces	500	10.21 $\pm$ 1.48	28.69 (26.38-31.30)	7.67	1.23

<sup>a</sup>cypermethrin = 0.39 g[AI]/cm<sup>2</sup>, chlorpyrifos = 11.7  $\mu$ g[AI]/cm<sup>2</sup>, propoxur = 43  $\mu$ g [AI]/cm<sup>2</sup>.

<sup>b</sup>Total number of observations recorded until 80% mortality was achieved (repeated measure).

<sup>c</sup>IR = inhibition ratio ( $LT_{50}$  contaminated surface/ $LT_{50}$  clean surface).

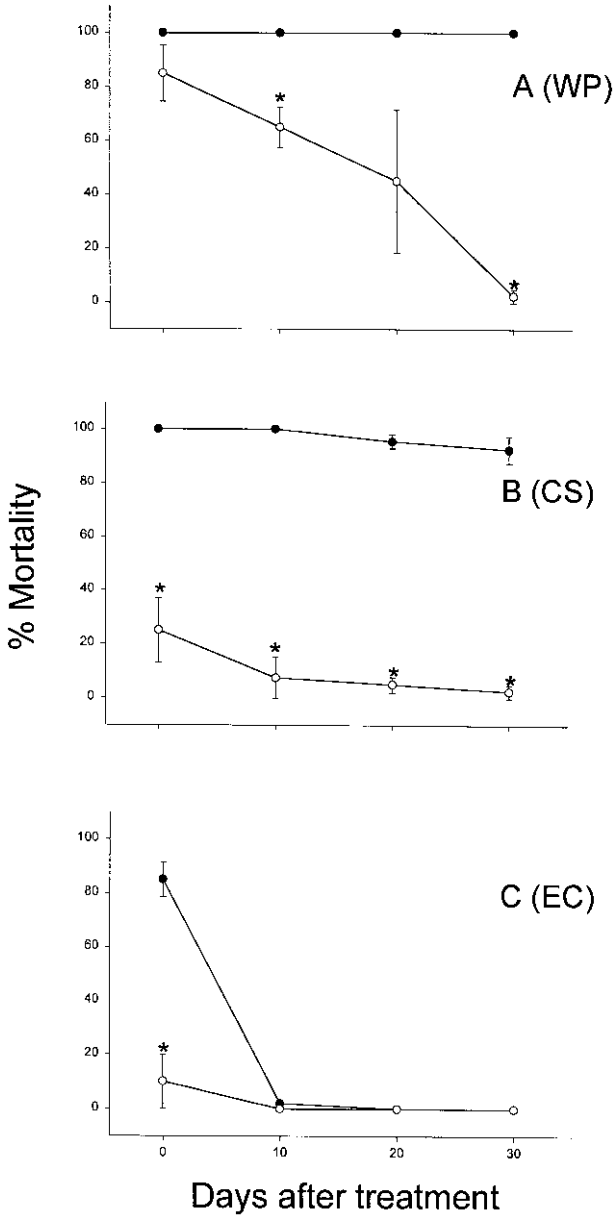


Fig. 1. Residual efficacy of 3  $\lambda$ -cyhalothrin-cyhalothrin formulations (A, wettable powder; B, capsulated suspension; C, emulsifiable concentrate) applied to glass Mason jars in the presence (○) and absence (●) of German cockroach feces.

of propoxur, Baygon 1.5 EC, was least affected by the presence of feces. The effectiveness of another carbamate, bendiocarb, was unaffected by soil carbon content (Kamm & Montgomery 1990).

Dramatic losses in  $\lambda$ -cyhalothrin efficacy were observed in the longevity experiments. For example, although the WP and CS formulations caused 95 to 100% mortality through 30 d in the absence of feces, their efficacy was reduced to nearly 0% mortality in the presence of feces at day 30.

Cockroach feces in the home may present problems other than control failures. Human consumption of food products contaminated with cockroach feces may lead to digestive disorders (Mullins & Cochran 1973) and feces often contain bacterial and fungal pathogens (Koehler et al. 1990). Additionally, cockroach feces contain potent allergens responsible for asthma and related respiratory disorders (Brenner 1995). Therefore, cleaning cockroach feces from structures before insecticide treatment provides a 2-fold benefit—reduction of disease potential and improved insecticide efficacy.

#### ACKNOWLEDGMENTS

We thank R. S. Patterson, J. Hogsette, (USDA-ARS, Center for Medical, Agricultural and Veterinary Entomology, Gainesville, Florida) and S. J. Yu (University of Florida, Department of Entomology and Nematology) for critical reviews of the manuscript. We thank Priamo Mena and Deanna Harrison for technical assistance. This is Florida Agricultural Experiment Station Journal Series No. R-06821.

#### INTERPRETIVE SUMMARY

A commonly used insecticide application method known as crack and crevice treatment, was simulated in the laboratory to evaluate the effect of cockroach excrement found in these areas on insecticide efficacy. The presence of cockroach excrement significantly decreased the efficacy of several emulsifiable concentrate insecticides (chlorpyrifos, cypermethrin, and propoxur). The efficacy of other insecticide formulations (Wettable Powder, and Capsulated Suspension) were also decreased in the presence of cockroach excrement. These results help to explain control failures when this method of insecticide application is employed. Recommendations for improving the method are suggested.

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