

BIOEFFICACY OF CHLORFENAPYR AGAINST AMERICAN AND ORIENTAL COCKROACHES, AND HOUSE FLIES ON WOOD, CONCRETE, AND VINYL SURFACES

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Abstract This research was conducted to determine biological activity of Phantom SC (chlorfenapyr) on wood, concrete, and vinyl surfaces. The experimental design was a 3 x 3 x 3 factorial (3 treatments, 3 surfaces, and 3 insect-pests). Each experimental unit consisted of a rigid-plastic cage (109 x 49.5 x 17 cm) with wood, concrete, or vinyl surfaces affixed to the bottom. The surface in each arena was sprayed with 0.37 or 0.50% chlorfenapyr. Insect populations were confined to pre-assigned units and covered with a lid. Insect mortality was observed for 28 and 5 days in cockroach and house fly experiments, respectively. Phantom SC (0.5%) yielded 100, 96, and 90% mortality in American cockroaches on wood, vinyl, and concrete surfaces, respectively. Chlorfenapyr 0.5% provided 100, 97, and 85% mortality in Oriental cockroaches on concrete, wood, and vinyl surfaces, respectively. Chlorfenapyr 0.37 and 0.5% caused 100% mortality in house flies on all treated surfaces after 4.5 days. Residual efficacy trials (29-42 days after initial treatment) with chlorfenapyr 0.5% against American cockroaches produced 87, 84, and 58% mortality on cement, vinyl, and wood surfaces, respectively. Our data indicates that Phantom SC is very efficacious on wood, concrete, and vinyl surfaces against cockroaches and house flies.

Key Words Phantom SC, household surfaces

INTRODUCTION

There are many general insect pests which invade or dwell in or near the exterior of structures within the urban environment. Three of these general insect pests include: the American cockroach, *Periplaneta americana* L.; the Oriental cockroach, *Blatta orientalis* L.; and the House fly, *Musca domestica* L. Cockroaches are one of the most commonly encountered household insect pests in the United States, even though only a few species (10 of 70 total species in the United States) structures (Bennett et al., 2003; Barcay, 2004). Cockroaches live in unsanitary conditions, have the potential to spread disease organisms through foraging activity, and cause allergic reactions in humans from exposure to feces and cast skins. Anthropomorphically, cockroaches in and around structures have become a zero tolerance pest. American and Oriental cockroaches have been documented to forage in areas around their preferred daytime harborage sites. Due to their foraging behavior, cockroaches are commonly seen in and around base of structures (Bennett et al., 2003; Barcay, 2004).

The common house fly is a worldwide pest and is developing a social stigma similar to that of cockroaches. The preferred oviposition sites for house flies include: animal waste, garbage, and decaying organic matter (Bennett et al., 2003). Thus, house flies also have the potential to spread disease causing organisms in areas around urban structures. House flies are commonly active during daylight and can be found resting on floors, walls, and ceilings indoors as well as plants, groundcover, or any other similar surfaces outdoors (Bennett et al., 2003).

There are many products registered to manage populations of structure infesting cockroaches and house flies. These products are formulated as baits (liquid, gel, or granular), dusts, granules, emulsifiable concentrates (EC), suspension concentrates (SC), and wettable powders (WP). Cockroach control practices include the use of baits, dusts, insecticide based residual perimeter sprays, insecticide based non-residual flushing agents or a combination of two or more of these tactics (Bennett et al., 2003; Ehmann, 1997), while house fly control strategies rely most heavily on the use of insecticide based residual sprays, non-residual sprays or physical control (e.g., fly sticky strips).

Phantom® SC termiticide-insecticide is a newly registered general pest control product with an active

ingredient (AI), chlorfenapyr. Chlorfenapyr is a member of the pyrroles, a relatively new class of insecticide. Chlorfenapyr is a pro-insecticide that requires activation by another molecule to exhibit its insecticidal activity (Black et al., 1994). Microsomal mixed function oxidases, specifically the cytochrome P450 gene family, activate chlorfenapyr through an oxidative reaction (Black et al., 1994). The product of this reaction uncouples oxidative phosphorylation within the mitochondria causing a decrease in adenosine triphosphate (ATP) production and eventually cellular/organismal death [U.S. Environmental Protection Agency (EPA) 2001]. Since the efficacy of Phantom SC on different surfaces against American and Oriental cockroaches, and house flies has not been fully evaluated, this research was undertaken to rectify the existing deficiency.

The objectives of this study were to: 1) evaluate the biological activity of Phantom SC (chlorfenapyr) on three surfaces (wood siding, vinyl siding, and concrete slab) against American cockroaches, Oriental cockroaches, and the house flies when applied as a 90 cm spray-band-treatment; and 2) assess residual effect of Phantom SC (chlorfenapyr) against American cockroaches on wood, vinyl and concrete surfaces.

MATERIALS AND METHODS

Insect and Rearing

The American and Oriental cockroach colonies used in this study were purchased from the Sierra Research Laboratories, Modesto, CA 95357 and were subsequently reared on a diet of Purina Cat Food. The pupae of house flies used in this study were acquired from the United States Department of Agriculture Midwest Livestock Pest Research Unit, Lincoln, Nebraska.

Insecticide

Phantom® SC termiticide-insecticide (21.45% chlorfenapyr, Lot # 8289S01CD) was provided by BASF Corp., Research Triangle Park, NC 27709.

Cockroach Study

The experimental design used for the acute efficacy of chlorfenapyr was a 3 x 3 x 3 factorial (3 treatments, 3 surfaces, 3 insect-pests) with three replications for each combination of treatments. A total of 81 experimental units were set up (Table 1). For evaluating efficacy of chlorfenapyr against American and Oriental cockroaches, each experimental unit was constructed within a Rubbermaid® Fashion Clear XL storage tote (109 x 49.5 x 17 cm). For the cockroach/concrete surface treatments, U-Mix Ready Mix concrete was poured (~ 4 cm thick) into the tote and trowelled to a smooth finish. Once the concrete had dried, each unit was measured to allow a 90 cm chlorfenapyr treatment zone as well as food/water zones at each end of the unit outside of the treatment zone. A harborage zone (egg carton) was also established at one end of the experimental unit outside of the treatment zone (Figure 1).

Table 1. Experimental design for insecticide efficacy on three different surfaces against three insects (American and Oriental cockroaches, and house flies).

Treatments	Treated Surfaces	N° of Pests	Replications
0.37% AI Chlorfenapyr (Phantom SC)	Wood Siding	3	3
	Vinyl Siding	3	3
	Concrete Slab	3	3
0.50% AI Chlorfenapyr (Phantom SC)	Wood Siding	3	3
	Vinyl Siding	3	3
	Concrete Slab	3	3
Untreated Control (water only)	Wood Siding	3	3
	Vinyl Siding	3	3
	Concrete Slab	3	3

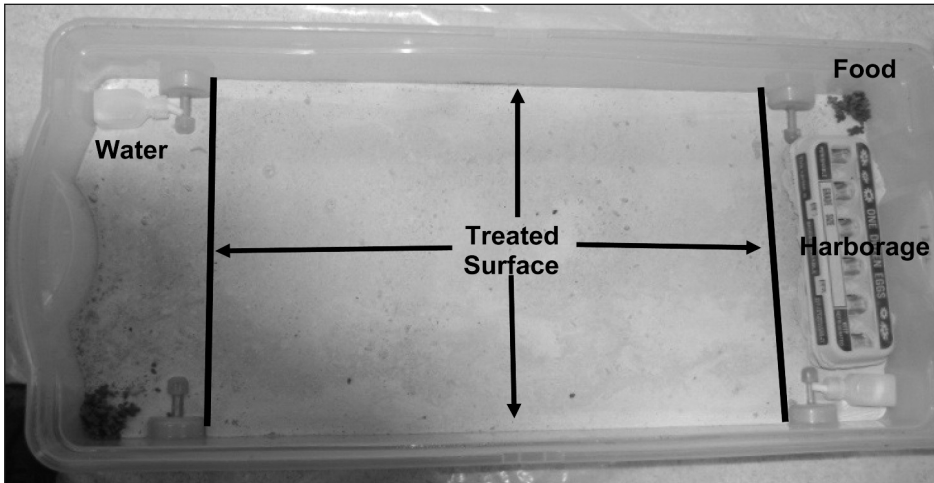


Figure 1. Experimental unit set up with a concrete surface for acute efficacy of chlorfenapyr against American and Oriental cockroaches.

For wood and vinyl siding surfaces, plywood was mounted within each storage tote to provide a platform on which the wood or vinyl sidings were mounted (Figure 2). The setup of food/water/harborage areas for each cockroach/wood or vinyl siding experimental unit was the same as described for the units with concrete surface. Prior to treatment, the test population ($n = 15-20$) of cockroaches (American or Oriental) were placed in each experiment-unit and allowed to acclimate for 7 days and to establish foraging areas on each surface. Each test population consisted of a mixed population of adult (male and female) and late instar nymphs.



Figure 2. Experimental unit set up with wood or vinyl siding surface for acute efficacy of chlorfenapyr against American and Oriental cockroaches.

House Flies

To determine acute efficacy of chlorfenapyr against house flies, experimental units were constructed differently than those used for the cockroaches. Concrete surface units were poured similarly to those used for the cockroach study

but wood strips were mounted on the concrete after drying. Wire mesh [aluminum insect wire screening, 91.44 x 76.2 cm (0.011 cm diameter)] was attached to the wood strips to form a concave foraging arena for each experimental unit (Figure 3). For the wood siding surfaces, the wire mesh was screwed directly into the treated surface (after treated surface had dried). The treated vinyl siding surface was mounted first on to plywood and then the wire mesh was screwed directly into the vinyl siding (Figure 4). Each house fly experimental unit had water, a food source (granulated sugar with condensed milk), and a dish with 25 house fly pupae placed in it after surface treatment had completely dried (Figure 3). House fly populations were assumed to be mixed with both male and female flies.

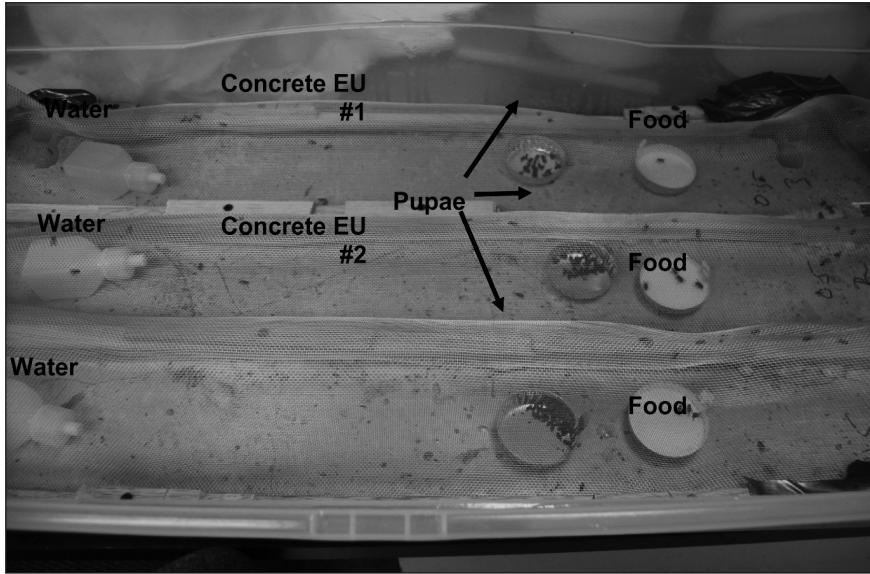


Figure 3. Experiment set up for concrete surface to delineate acute efficacy of chlorfenapyr against house flies. A 90 cm long x 12.5 cm wide wood strip was covered with 25 cm wide aluminum mesh to form a concave foraging arena.



Figure 4. Experiment set up for wood and vinyl surfaces to delineate acute efficacy of chlorfenapyr against house flies. A 90 cm long x 12.5 cm wide strip was covered with 25 cm wide aluminum mesh to form a concave foraging arena.

Residual Effect Against American Cockroaches

The experiment design used for the residual efficacy portion of this study was a 3 x 3 x 1 factorial (3 concentrations AI x 3 surfaces x 1 urban insect pest (American cockroach) with 3 replications for each combination of treatments (a total of 27 experimental units). The experimental units used in this residual study were the same units used for acute efficacy trials for American cockroaches. A total of 50 adult American cockroaches were placed on each

treated surface (wood siding, concrete, or vinyl siding) to assess residual efficacy of chlorfenapyr dilution. For the residual study, the harborage and food/water were moved directly in the middle of the treated zone, thereby forcing the cockroaches to remain on the treated surface (Figure 5).



Figure 5. Experiment setup for residual activity of Phantom SC (chlorfenapyr) against American cockroaches.

Insecticide Treatments, Application, and Sampling Procedures

Chlorfenapyr was mixed to a 1.89 liters solution each at 0.37% and 0.50% AI according to label directions. Chlorfenapyr was applied to all surfaces with a new B&G Hand Pump Sprayer to the point of insecticide solution run-off on the surface using a coarse flat-fan tip (Figure 6). The B&G sprayer tanks were shaken thoroughly to ensure homogeneity of each insecticide mixture. Each treatment received approximately 0.19 liter of insecticide solution (wood and concrete surfaces required slightly more insecticide than vinyl to reach run off). Prior to treatment, insects were barricaded away from the treatment zone (cockroach units) or kept off treated surface (pupae dish in house fly units) until treated surface was completely dry (Figure 7). After the treated surfaces had dried, the cockroaches were allowed to re-establish movement across treated surfaces and housefly pupae in petri dishes were placed in the experimental units.



Figure 6. Chlorfenapyr spraying on concrete, wood or vinyl surface to the point of run-off with a B&G Sprayer equipped with flat-fan tip.

Cockroach Mortality Data

In the acute efficacy trials for the American and Oriental cockroaches, post-treatment cockroach mortalities were recorded at 1 hour after treatment, 1 day after treatment (dat), 3, 7, 14, and 28 dat. In the residual efficacy trials for the American cockroach counts were performed at 29, 31, 35, and 42 dat to calculate % mortality of the test population.

House Fly Mortality Data

In the acute efficacy trials for the house flies, post-treatment fly counts were performed at 2 dat (point of adult emergence), 2.5, 3, 3.5, 4, 4.5, and 5 dat to calculate percentage mortality of the test population.

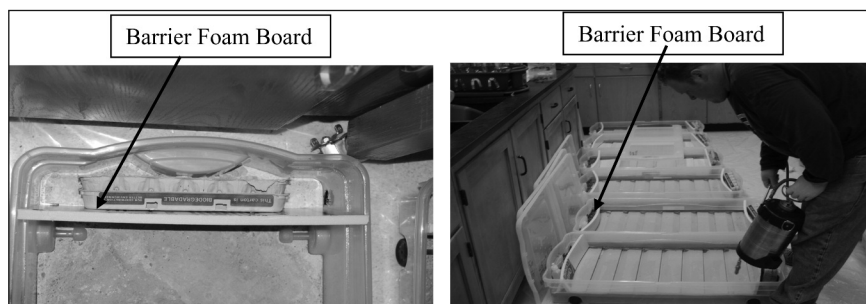


Figure 7. Exclusion barriers to stop cockroaches and house flies from entering treatment zone.

Calculating Percentage Mortality in Test Pest Population

Percentage mortality was evaluated using pre- and post-treatment pest populations using the equation as follows:

$$[(T_0 - T_i) / T_0] * 100 = \% \text{ mortality of test pest population}$$

T_0 = Pre-treatment test pest population

T_i = Post-treatment test pest population at the “ith” monitoring interval.

Data Analysis

Mean percentage mortality of American/Oriental cockroaches and house fly populations for each treatment combination (acute and residual activity assays, AI concentration, surface type) at each collection interval were analyzed using Proc Mixed (SAS v. 9.1, 2003) with statistical significance tested by differences of least squared means (student’s t-test ($P < 0.05$)).

RESULTS

Acute Efficacy of Chlorfenapyr Against American Cockroaches

Wood Surface. There were no significant differences in American cockroach mortality between 0.37 and 0.50% chlorfenapyr treatments at 1 hour after treatment, 1 or 3 dat (Figure 8). The % cockroach mortality in the 0.37% and 0.50% AI treatments at 7, 14, and 28 dat was significantly greater than the control, and the 0.50% AI treatment had significantly greater % cockroach mortality than the 0.37% AI treatment.

Concrete Surface. No significant differences were discerned in percentage cockroach mortality between 0.37 and 0.50% chlorfenapyr treatments at 1 hour after treatment, 1 or 3 dat (Figure 8). At 7 dat, the 0.50% AI treatment had significantly greater % mortality than the 0.37% AI treatment and the control treatment. At 14 and 28 dat, percentage cockroach mortality within the 0.37% and 0.50% AI treatments was significantly greater than that of the control, and the 0.50% AI treatment had greater percentage mortality than the 0.37% AI treatment.

Vinyl Surface. No significant differences were observed in percentage cockroach mortality between 0.37 and 0.50% AI treatments at 1 hour after treatment, 1 or 3 dat (Figure 8). At 7, 14, and 28 dat; however, the % mortality in the 0.37% and 0.50% AI treatments was greater than the control.

When comparing surface treatment types across all concentrations of chlorfenapyr, there were no significant differences observed at 1 hour after treatment, 1 dat, or 3 dat ((Figure 8). At 7 and 14 dat, mean percentage mortality within the 0.50% AI applied to wood as well as vinyl at both 0.37% and 0.50% AI was significantly greater than all other treatments. At 28 dat, the 0.50% AI on wood, concrete, and vinyl treatments resulted in significantly greater percentage cockroach mortality than other treatments.

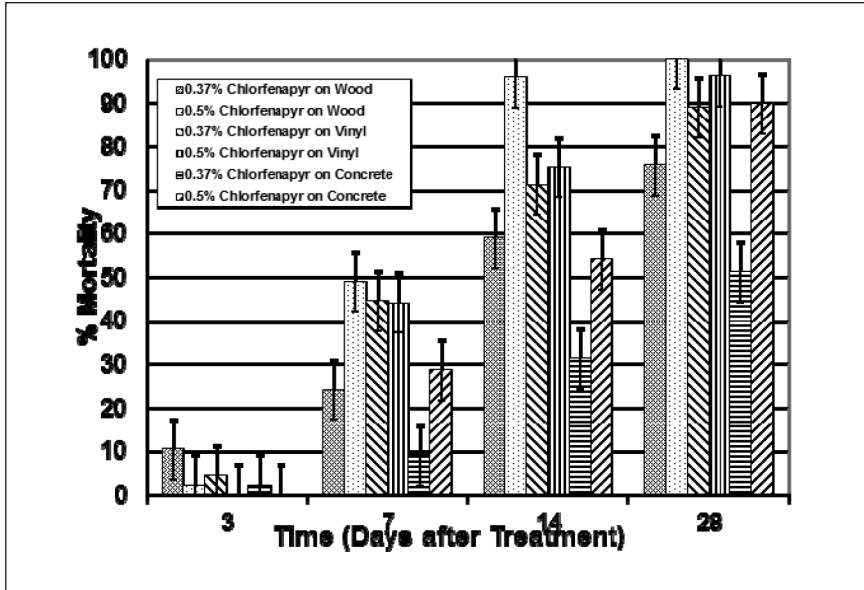


Figure 8. Bioefficacy of chlorfenapyr against the American cockroaches when applied on wood, concrete and vinyl surfaces. n= 15 cockroaches/replication, 3 replications per treatment.

Acute Efficacy of Chlorfenapyr Against Oriental Cockroaches

Wood Surface. No significant differences in mortality of Oriental cockroaches were observed between 0.37 and 0.50 % AI chlorfenapyr treatments at 1 hour after treatment and

1 dat (Figure 9). At 3, 7, 14, and 28 dat; however, % mortality in 0.37% and 0.50% AI treatments was significantly greater than control.

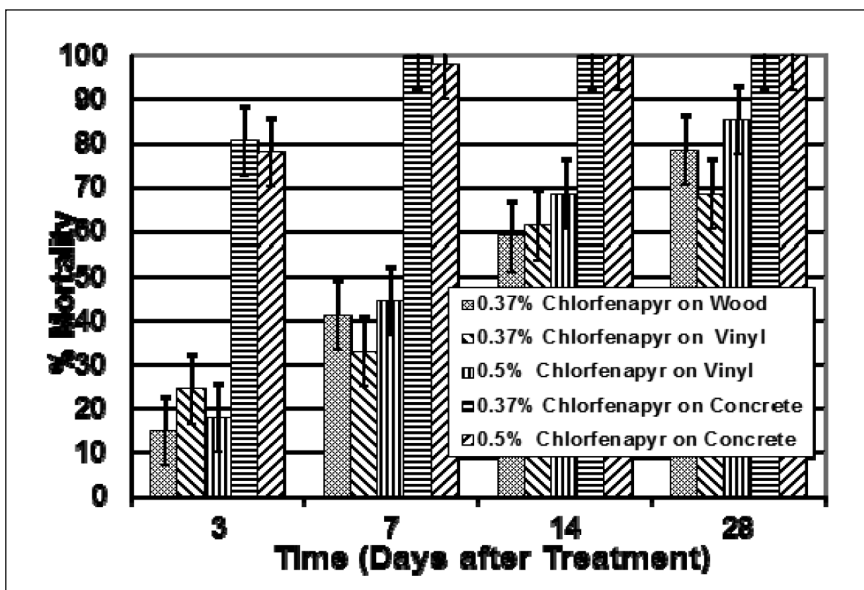


Figure 9. Bioefficacy of chlorfenapyr against the Oriental Cockroaches when applied on wood, concrete and vinyl surfaces. n= 15 cockroaches per replication, 3 replications per treatment.

Concrete Surface: There were no significant differences in percentage cockroach mortality between 0.37 and 0.50 % AI treatments at 1 hour and 1 dat (Figure 9). At 3, 7, 14, and 28 dat; however, both concentrations yielded significantly greater mortality than the control.

Vinyl Surface. Cockroach mortality was not significantly different in 0.37 and 0.50% AI treatments at 1 hour after treatment and 1 dat (Figure 9). At 3, 7, 14, and 28 dat, both these treatments had significantly greater cockroach mortality than the control.

When comparing efficacy of chlorfenapyr concentrations across all surfaces, there were no significant differences at 1 hour after treatment or 1 dat (Figure 9). At 3 dat, the concrete surface (both 0.37% and 0.50% AI) provided significantly greater mortality than all other treatments. At 7 and 14 dat, mean percent mortality within the 0.50% AI wood treatment as well as the concrete treatment at both 0.37% and 0.50% AI was significantly greater than all other treatments. At 28 dat, the 0.50% AI wood, 0.37% and 0.50% AI concrete, and the 0.50% vinyl treatments AI showed significantly greater biological activity than the 0.37% vinyl treatment.

Acute Efficacy of Chlorfenapyr Against House Flies

The mean percentage mortalities of House flies in acute efficacy trials are presented in Figure 10. The flies in control treatment on all surfaces survived for more 20 days.

Wood Surface. There were no significant differences in house fly mortality between 0.37% and 0.50% AI treatments at 2 and 2.5 dat (Figure 10). At 3 and 4.5 dat, percentage mortality within the 0.37% and 0.50% AI treatments was greater than that of the control.

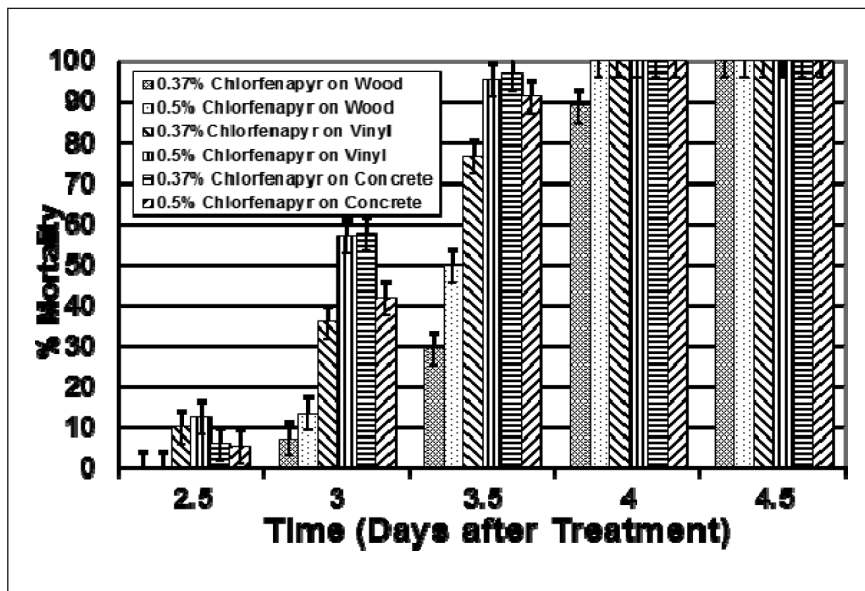


Figure 10. Bioefficacy of chlorfenapyr against house flies when applied on wood, concrete and vinyl surfaces. $n = 25$ flies per replication, 3 replications per treatment.

At 3.5 and 4 dat, percentage mortality within the 0.37% and 0.50% AI treatments was significantly greater than that of the control, and the 0.50% AI treatment had significantly greater percentage mortality than the 0.37% AI treatment.

Concrete Surface: No significant differences were determined in percentage house fly mortality between 0.37% and 0.50% AI treatments at 2 and 2.5 dat (Figure 10). At 3 dat, % mortality within the 0.37% and 0.50% AI treatments was significantly greater than the control, and the 0.50% AI treatment had significantly greater % mortality than the 0.37% AI treatment. At 3.5, 4, and 4.5 dat, percentage mortality within the 0.37% and 0.50% AI treatments was significantly greater than that of the control, but not different from each other.

Vinyl Surface. No significant differences were observed in percentage house fly mortality between 0.37% and 0.50% AI treatments at 2 dat (Figure 10). At 2.5, 4, and 4.5 dat, % mortality within the 0.37% and 0.50% AI treatments was significantly greater than that of the control, but not different from each other. At 3 and 3.5 dat, percentage mortality within the 0.37% and 0.50% AI treatments was significantly greater than that of the control, and the 0.50% AI treatment had significantly greater % mortality than the 0.37% AI treatment.

When comparing surface types across all concentrations of chlorfenapyr, there were no significant differences observed at 2 dat (Figure 10). At 2.5 dat, 0.37% and 0.50% AI applied to vinyl siding yielded significantly greater mortality than 0.37 and 0.50% AI applied to wood. At 3 dat, the 0.50% AI on vinyl and the 0.37 AI on concrete surface showed significantly higher biological activity than all other treatments. Also, the 0.37% AI on vinyl and 0.50% AI on concrete surface provided significantly better mortality than either of the wood siding. At 3.5 dat, 0.50% chlorfenapyr applied to concrete surface and vinyl provided significantly greater house fly mortality than all other treatments. At 4 dat, the 0.37% wood treatment provided significantly less % mortality than all other treatments. At 4.5 dat, no significant differences were detected amongst insecticide treatments as all treatments provided 100% mortality of house fly populations.

Residual Efficacy of Chlorfenapyr Against American Cockroaches on Wood, Vinyl and Concrete Surfaces

Within the wood surface trials, there were no significant differences between percentage AI concentration treatments at 29 dat. At 31 dat, the 0.37% AI treatment was significantly different from the control treatment (Figure 11). At 35 dat, both the 0.37% and 0.50% AI treatments provided significantly better efficacy than the control treatment, but the 0.37% AI treatment provided significantly better control than the 0.50% AI treatment. At 42 dat, both % AI treatments significantly outperformed the control treatment, but were not significantly different from each other. Within the concrete treatments, there were no significant differences between percent AI concentration treatments at 29 and 31 dat. At 35 dat, both percentage AI treatments significantly outperformed the control treatment, but were not significantly different from each other. At 42 dat, both percentage AI treatments were significantly higher than the control treatment, but the 0.50% AI treatment provided significantly better control than the 0.37% AI treatment.

Within the vinyl trials, there were no significant differences between percentage AI concentration treatments at 29 and 31 dat. At 35 dat, the 0.50% AI treatment provided significantly higher percentage mortality than the control treatment. At 42 dat, both the 0.37% and 0.50% AI treatments provided significantly better efficacy than the control treatment, but the 0.50% AI treatment provided significantly better control than the 0.37% AI treatment.

When comparing surface treatment types across all concentrations of chlorfenapyr, there were no significant differences observed at 29 and 31 dat (Figure 11). At 35 dat, 0.37% AI wood and 0.50% AI vinyl treatments were significantly more efficacious than the 0.50% AI wood siding, 0.37% AI vinyl siding, and 0.37% AI concrete treatments. At 42 dat, the 0.50% AI vinyl siding and the 0.50% AI concrete treatments showed significantly higher biological activity than all other treatments except 0.37% AI wood surface.

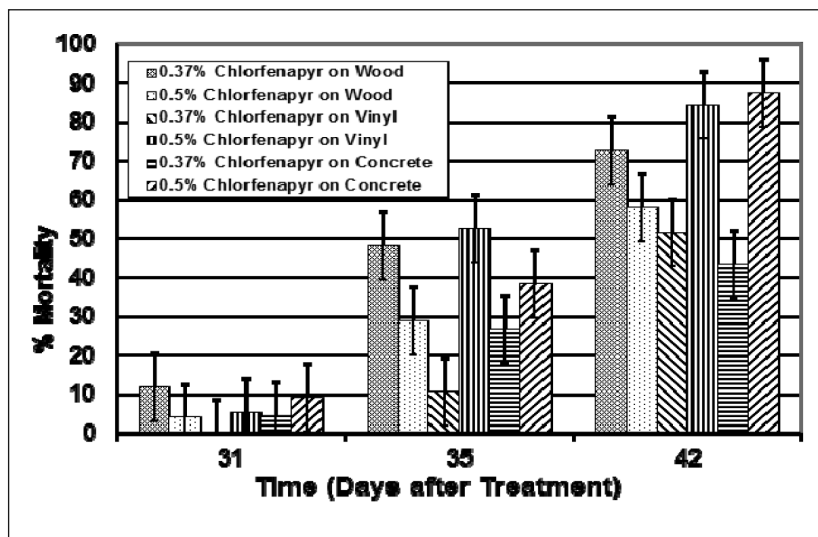


Figure 11. Residual efficacy of chlorfenapyr against the American cockroaches confined to surfaces after 29 days from initial treatment, n=50 cockroaches per replication, 3 replications per treatment.

DISCUSSION

When examining the data generated in this study a few general trends emerge. Phantom SC is an effective acute (and residual for American cockroaches) insecticide at both the lower and higher concentrations against the three urban insect pests screened. It seems most efficacious (least amount of time to reach 100% mortality) against house flies, followed by Oriental cockroaches, and then American cockroaches. Perhaps one reason for this trend would be the smaller size of both the house fly and Oriental cockroach in comparison to American cockroaches.

A smaller body size would require less of a dose (or less time within a dose) to elicit a response. Thus, faster % mortality would be expected from smaller insects. Another possible explanation of this trend could rely on the pro-insecticide nature of Phantom SC. There are different cytochrome P450 microsomal mono-oxygenase isoforms within insects which lead to the increased or decreased activation of chlorfenapyr into its active form (Scott and Wen, 2001; Feyereisen, 2006). Another interesting trend observed is the increased % mortality of house flies and Oriental cockroaches on concrete surfaces treated with either concentration of Phantom SC. Possible explanations for this trend both revolve around routes of exposure from the porous concrete surface to the insect. In the case of house flies, they are known to regurgitate food back out onto surfaces and then sponge feed on the regurgitated/liquefied food to enable proper nutrient absorption (Caron, 1999). This behavior may lead to an increased oral exposure which when coupled with the dermal exposure (of the flies touching the treated surface) may lead to the increased efficacy of the insecticide. Oriental cockroaches also moved their food away from the non-treated zones and drug it around the experimental unit where it may have been exposed to insecticide residues and then ingested.

SUMMARY AND CONCLUSIONS

Based on our research data, Phantom SC termiticide-insecticide (chlorfenapyr) is extremely efficacious against American and Oriental cockroaches, and house flies when applied on wood, concrete and vinyl surfaces under laboratory conditions. Chlorfenapyr was also effective as a residual insecticide after aging for 28 days against American cockroaches. This study simulates the chlorfenapyr application as a 0.9 m treatment zone around the exterior perimeter of a structure. Further, we speculate that a 0.9 m treatment zone applied up the side of a structure would be helpful and may be efficacious in controlling urban pests, and that this use pattern should be considered for future pest control options.

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