

Evaluation of an Insecticide Dust Band Treatment Method for Controlling Bed Bugs

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ABSTRACT Current bed bug, *Cimex lectularius* L., control usually involves insecticide applications that pose a high risk of insecticide exposure to residents and applicators. To minimize these risks and the amount of insecticides used, we designed and evaluated a dust band treatment technique. The laboratory assay showed that 1% cyfluthrin dust treated bands are highly effective in killing bed bugs. We further evaluated this technique in bed bug infested apartments. The “dust band” treatment consisted of installing a 3.8-cm-wide fabric band on furniture legs and brushing Tempo dust (1% cyfluthrin) (Bayer Environmental Science, Research Triangle Park, NC) onto the bands. In addition, interceptors were installed under furniture legs. Alpine (0.5% dinotefuran) aerosol spray was applied directly to live bed bugs found on furniture during biweekly inspections. This treatment was compared with two other treatments: “integrated pest management” (IPM) and “control.” The IPM treatment included dust bands plus the following: applying hot steam to infested furniture and surrounding areas, installing mattress encasements, applying 1% cyfluthrin dust around room perimeters, and installing interceptors under furniture legs. Alpine aerosol was applied to live bed bugs found during biweekly inspections. In the control group, the apartments received cursory treatment with insecticide sprays by the existing pest control contractor hired by the property management office. Bed bug numbers before and after treatments were determined based on biweekly interceptor counts or a combination of interceptor counts and visual inspections. From 0 to 12 wk, mean bed bug counts of the dust band, IPM, and the control treatment decreased by 95, 92, and 85%, respectively. Both dust band and IPM resulted in higher bed bug reduction than the control. There was no significant difference in the final counts between dust band and IPM treatments. An additional field experiment showed installing 1% cyfluthrin dust band and interceptors in lightly infested apartments prevented bed bug population rebound. Results indicate applying insecticide dust bands to furniture legs is an effective bed bug control technique.

KEY WORDS bed bug, *Cimex lectularius*, dust, infestation, control

The common bed bug, *Cimex lectularius* L. (Hemiptera: Cimicidae), is extremely difficult to control because it is nocturnal, seeks cryptic harborages, and is resistant to most of the registered insecticides (Usinger 1966, Romero et al. 2007, Zhu et al. 2010). There is no single insecticide treatment that is highly effective against bed bugs. Complete eradication of an established infestation is extremely difficult to accomplish in a single service visit and most pest management professionals (PMPs) need two to three visits to “control” (not necessarily eradicate) bed bugs despite the use of multiple insecticides (Potter et al. 2010). Nonchemical tools such as mattress encasements, hot steam machines, sanitation, vacuuming, and diligent moni-

toring are recommended for managing infestations (Wang et al. 2009, Doggett 2011). Although nonchemical tools increase the probability of a successful treatment, they offer no residual protection. As a result, the necessity to apply insecticides is likely to remain high in the foreseeable future.

Insecticides often are applied extensively to increase the probability that bed bugs will be killed when they crawl over the insecticide residues. Because bed bugs may occur in all rooms of a home, PMPs tend to apply pesticides in all rooms regardless of the locations where the bed bugs actually are found (Wang and Cooper 2012). Similarly, consumers often use large amounts of insecticide sprays and dusts for bed bug control. As a result, the amount of insecticide used for bed bug control and the risk of human exposure to insecticides is much higher relative to other indoor pests such as cockroaches or ants.

Potter (2008) reported that 74% of the surveyed companies sprayed beds when treating for bed bugs. Pyrethroids are the dominant insecticides used by

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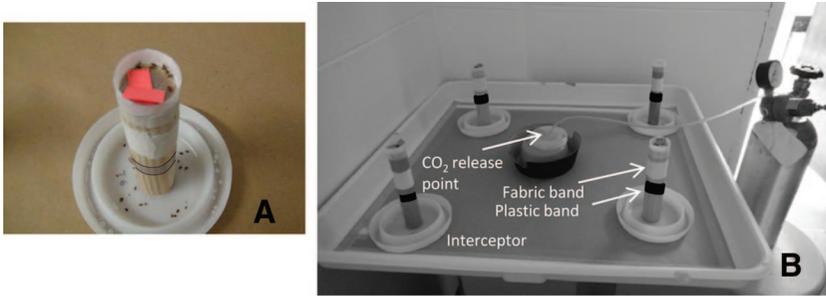


Fig. 1. Experimental setup evaluating the effectiveness of 1% cyfluthrin dust band treatment. (A) One experimental unit with a dish of bed bugs on the top, a wooden rod, and an interceptor; (B) four experimental units (replicates) in an arena with CO₂ released at center of the arena. (Online figure in color.)

PMPs as well as consumers (Potter et al. 2010). However, widespread resistance to commonly used insecticides (pyrethroids) is evident in many bed bug populations (Romero et al. 2007, Zhu et al. 2010). There is a strong interest in exploring more effective uses of the insecticides currently available for bed bug management. The goal of the current project was to test a novel insecticide application method for controlling bed bugs. The technique involved installing insecticide dust treated bands to furniture legs that would deliver the insecticide to bed bugs crossing the barrier. Climbug Insect Interceptors (Susan McKnight, Inc., Memphis, TN) referred to hereafter as “interceptors,” are placed under the furniture legs to provide an additional killing and monitoring mechanism. The underlying concept is that bed bugs travel frequently between furniture and the floors to search for host or disperse from the feeding site (furniture) after a bloodmeal. This was evident by the presence of high numbers of bed bugs found in intercepting devices placed under furniture legs (Wang et al. 2009).

Placing interceptors under the furniture legs can kill a significant number of bed bugs by confining the trapped bugs inside where they typically die within a few days to a week, presumably because of desiccation in the talc dusted well of the interceptor. However, interceptors are not 100% effective in preventing the movement of bed bugs or trapping all of the bugs that travel to beds and furniture where hosts sleep or rest. Our field observations show that interceptors placed beside walls (not under furniture legs) had an average of 19% of the trapped bugs in the inner well of interceptors during biweekly inspections (C. W. et al., unpublished data), indicating bed bugs fallen into the outer well could enter the inner well. Furthermore, those bugs already on the furniture may come down to the inner or outer well of the interceptors, and go back to the furniture without being trapped. Therefore, the placement of an insecticide dust treated band may increase the likelihood of killing bugs that were otherwise not trapped in the interceptors. Insecticide dusts are highly effective against both nonresistant and resistant bed bugs (Romero et al. 2009). We tested this novel method both in the laboratory and in bed bug infested apartments. We hypothesized that the insecticide dust band treatment would re-

duce the need for more extensive pesticide applications, although providing a satisfactory level of bed bug control.

Materials and Methods

Laboratory Experiment. This experiment evaluated the behavioral and mortality response of bed bugs to Tempo dust (1% cyfluthrin) (Bayer Environmental Science, Research Triangle Park, NC) treated fabric bands. The study was conducted in four plastic arenas (80 cm long by 75 cm wide by 5 cm high) with bottoms lined with brown paper (Fig. 1). Four interceptors were placed in each arena, one in each corner. These interceptors were washed and coated with a layer of fluoropolymer resin (BioQuip products, Rancho Dominguez, CA) to prevent bed bugs from escaping. A wooden rod (16.5 cm tall, 3.5 cm in diameter) was placed in each interceptor. A 3.8-cm-wide band of sports tape (Johnson & Johnson, New Brunswick, NJ) and a 2-cm-wide band of smooth plastic tape were placed around the wooden rod. The two bands were separated approximately by 2 cm to provide untreated wooden surface, where bed bugs that crossed the treated fabric band could walk or stay on before reaching the plastic tape. A 3.7-cm-diameter plastic dish was placed on top of the wooden rod to hold bed bugs. The interior and exterior surfaces of the dishes were covered with a paper surgical tape (Caring International, Mundelein, IL) to facilitate bed bug movement. The smooth band on the wooden rod prevented bugs that fell into the interceptors from returning to the plastic dish on top of wooden rod, thus, allowing us to evaluate the mortality of those bugs that crossed the treated band. Cyfluthrin dust was applied to the fabric bands by using a 2.5-cm-wide foam brush. Each band received an average 0.138-g dust (5.0 mg/cm²). In each arena, two diagonally facing wooden rods were treated with 1% cyfluthrin dust, the other two served as a control. Four arenas were used, providing eight replicates for each treatment. After applying the dust, the wooden rods were glued to the interceptors.

A field-collected strain of bed bugs was used in the test. The bed bugs were collected from infested apartments and had been maintained in the laboratory for 3 yr. They were fed with defibrinated rabbit blood

every 7 d and maintained at $26 \pm 1^\circ\text{C}$ and a photoperiod of 12:12 (L:D) h. The bugs were starved for 1 wk before the experiment. Our previous studies showed these bugs to be moderately resistant to deltamethrin (C. W., unpublished data).

Thirty bed bugs (15 males, 15 third-fifth-instar nymphs) were conditioned in same sized dishes for 24 h before transfer to the small petri dish on top of the wooden rod. Each petri dish contained a piece of red paper as harborage. At 2 h after entering the dark cycle, the bed bugs were transferred to the dishes on top of the wooden rods (Fig. 1). After the transfer of bugs, CO_2 was released at 100 ml/min into the center of the arena for 3 h to stimulate host searching behavior. The bed bug activities from two wooden rods were recorded using a Sony digital HD video camera recorder (HDR-SR11, Sony Corporation Electronics, Inc., San Diego, CA) for 1 hr to determine 1) whether bed bugs exhibit distinct avoidance behavior toward the treated fabric, 2) what happens if they reach the plastic band, and 3) do bugs go back and forth crossing the treated fabric band. CO_2 was again released for 3 h on the second day of experiment at the same time period. Bed bug location and condition (healthy, moribund, or dead) were recorded at 3, 24, 48, 96, and 120 h.

Field Study Site. The field study was conducted in an eight-story apartment building in Newark, NJ managed by a private company. The building had 464 one-bedroom or studio apartments occupied by elderly tenants. A professional pest management company serviced the building monthly by applying insecticide sprays including D-Force HPX (0.06% deltamethrin, Waterbury Companies, Inc, Waterbury, CT) and Transport GHP (0.05% acetamiprid and 0.06% bifenthrin, FMC Corporation, Philadelphia, PA) for bed bugs. However, based on our interviews with the residents, many apartments were not serviced at monthly intervals and some bed bug infested apartments were never treated before and during the study.

Field Study I. A list of residents interested in participating in the study was obtained through the property manager. Interceptors (eight to 24 per apartment) were installed under furniture legs in each apartment. The interceptors were inspected after 2 wk. A visual inspection was conducted in eight apartments where the bed bug count in the interceptors was <5 . Twenty five infested apartments that had ≥ 9 bed bugs based on interceptor and visual inspection counts were selected for the study. The apartments were divided into three treatment groups: 1) 1% cyfluthrin dust bands on furniture legs plus insecticide aerosol on furniture where live bed bugs were found ($n = 8$); 2) 1% cyfluthrin dust bands on furniture legs plus installing mattress encasements, hot steam on furniture, 1% cyfluthrin dust around perimeter of the bed and sofa area, and insecticide aerosol on furniture where live bed bugs were found ($n = 8$); and 3) no treatment or insecticide spray treatment by the existing PMP ($n = 7$). The three treatments were referred to as dust band, IPM, and control, respectively.



Fig. 2. One percent cyfluthrin treated fabric band placed on a sofa leg for controlling bed bugs and foam brush used for applying the insecticide dust. (Online figure in color.)

The apartments were treated within a week of conducting the initial inspections. An educational brochure about bed bug biology and control was provided to all residents of the building. In the dust band treatment, a 3.8-cm-wide sports tape was applied around bed, sofa, and chair legs (Fig. 2). Next, 1% cyfluthrin dust was applied to the tape by using a 2.5-cm-wide foam brush. Alpine aerosol (0.5% dinotefuran, Whitmire Micro-Gen Research Laboratories, St. Louis, MO) was applied to cracks on furniture, box springs, and sofa seams where live bed bugs were found. In two apartments, a small amount (38 g) of Bedlam aerosol (0.4% phenothrin and 1.6% MGK 264, McLaughlin Gomley King Company, Minneapolis, MN) was used. In the IPM treatment, the mattresses and box springs were encased using Protect-A-Bed encasements (Protect-A-Bed, Chicago, IL). Steam (The Steamax, Amerivap Systems, Dawsonville, GA) was applied to bed frames, sofas, and chairs and reapplied if large number of live bed bugs were still found in follow up visits. One percent cyfluthrin dust bands were applied to furniture legs as in the dust band treatment. Alpine aerosol was applied to areas harboring live bugs found during biweekly inspections.

Residents in all treatment groups were asked to launder their clothing and bed linens regularly and eliminate "bridges" between furniture and the walls or floor. However, full resident cooperation was achieved in only nine out of the 25 apartments. In all apartments, interceptors were placed under the legs of beds, sofas, and tables and beside beds to monitor bed bug numbers. After the initial treatments, the apartments were inspected biweekly for 12 wk. One apartment in the dust band and one apartment in the control treatment were excluded from the study because of resident relocation. During each visit, the interceptors were examined, wiped clean with cotton balls, and then relubricated with talcum powder. A visual inspection of the furniture in the dust band and IPM group also was conducted whenever possible and live bugs were hand removed or killed using Alpine aerosol insecticide. Additional insecticide treatments were applied if needed in the dust band and IPM groups.

During the initial treatment, the total amount of insecticides used for treating the 16 apartments was as

follows: Alpine, 513 g; Bedlam, 38 g; Tempo dust, 88 g. In total, 251-g Alpine aerosol and 15-g Tempo dust were used between weeks 2 and 10. The control group did not receive treatments from the researchers. One PMP assigned to the building was scheduled to treat monthly, but only when the residents were present and only when the residents complained. Based on our interviews with the residents, the apartments were typically not treated on a monthly basis and the treatments were cursory.

Field Study II. This experiment was initiated immediately after the first experiment ended. The purpose of this experiment was to evaluate the effectiveness of dust band plus interceptor alone for suppressing bed bug infestations. It was compared with an untreated control group. Twelve apartments that were used in the first experiment were selected. Six of them were from the dust band group or the IPM group. The other six were from the PMP group. They had two to 18 bed bugs per apartment based on 2-wk bed bug counts from interceptors. One percent cyfluthrin was reapplied to the fabric bands in apartments from the dust band and PMP group and new interceptors were installed. This group was considered "dust band plus interceptor." The interceptors were replaced every 2 wk and bed bug counts from interceptors were recorded. Those apartments from the PMP group were left untreated and no interceptors were installed. After 4 wk, interceptors were installed for 2 wk to monitor bed bug numbers. This group was considered the "control" group.

Data Analysis. The laboratory experiment data (mortality and location) were subjected to analysis of variance (ANOVA) to test for differences between treatments or locations. Field bed bug counts from interceptor catches and/or visual inspections were analyzed using Proc Logistic procedure in SAS (SAS Institute 2008) to determine whether there were significant differences in bed bug counts among the treatments. Multiple comparison tests were conducted after a significant test using Proc Logistic. The residuals of the ANOVA analysis were checked using QQ normal plot and the normal distribution assumption was valid for ANOVA analysis of the percentage data in this experiment. No data transformation was needed.

Results

Laboratory Experiment. Most bed bugs actively moved around immediately after CO₂ was released into the arenas. Some bed bugs were observed repeatedly crossing the treated fabric bands without any apparent avoidance behavior. When the bugs encountered the smooth slippery plastic bands, they either fell off the rod into the interceptors or moved horizontally immediately above the plastic bands and then moved back to the dishes on top of the wooden rods. The mean percentage of bugs below the plastic tape at 3, 24, and 48 h after the initial release was significantly greater ($P < 0.05$) in the cyfluthrin band treatment compared with the control (Fig. 3). In the 1% cyfluthrin dust band treatment, bed bugs that fell

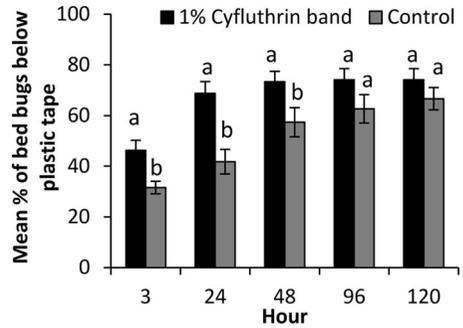


Fig. 3. Distribution of bed bugs (mean \pm SEM) after being released on top of wooden rods in the laboratory experiment. Bars of the same time period with different letters indicate significant differences (ANOVA, $P < 0.05$).

below the plastic band suffered $99 \pm 0\%$ mortality compared with $84 \pm 5\%$ mortality among bugs that remained above the plastic band at 5 d (Fig. 4). In the control, the mortality among those below and above the plastic band was 38 ± 9 and $7 \pm 2\%$, respectively. The differences in mortality between treatments within each location and between locations within each treatment were significant (ANOVA, $P < 0.05$). The total 5-d mortality in the cyfluthrin band treatment and the control was 94 ± 3 and $26 \pm 6\%$, respectively.

Field Experiments. The mean initial bed bug counts in the dust band, IPM, and control were 77, 55, and 109, respectively. The median (minimum, maximum) bed bug counts in the three treatments were 30.5 (20, 267), 19 (9, 277), and 42 (15, 405), respectively. There was no significant difference in the initial counts among treatments ($F = 1.0$; $df = 2, 20$; $P = 0.37$).

Bed bug counts declined rapidly in dust band and IPM treatment groups after the initial insecticide application (Fig. 5). There were significant differences in bed bug counts among the treatments at 12 wk. IPM and dust band treatment resulted in significantly higher bed bug reduction relative to the control (IPM versus control: $P = 0.0036$; dust band versus control: $P < 0.001$). There was no significant difference be-

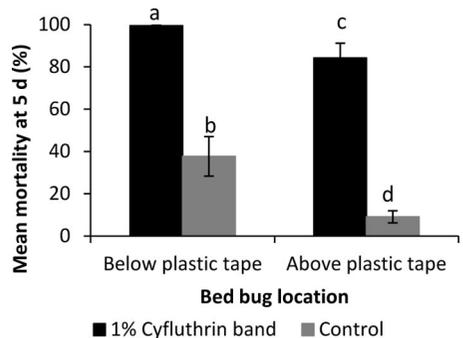


Fig. 4. Efficacy of 1% cyfluthrin dust band treatment against a field strain bed bugs in the laboratory experiment. Bars with different letters indicate significant differences (ANOVA, $P < 0.05$).

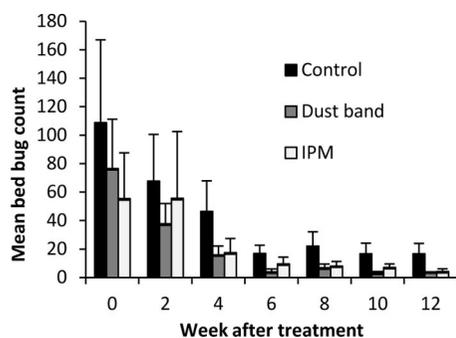


Fig. 5. Mean bed bug counts per apartment before and after treatments.

tween IPM and dust band treatment in the final bed bug count ($P = 0.0979$). At 12 wk, the mean bed bug counts in the dust band, IPM, and control group were: 4.0 ± 2.3 , 4.2 ± 1.8 , and 16.6 ± 7.4 , respectively. From 0 to 12 wk, the mean bed bug counts of the three treatments decreased by 95, 92, and 85%, respectively. The bed bug counts in the control also decreased rapidly after 2 wk. The reduction was probably because of the installation of interceptors that killed large numbers of bed bugs over time.

One apartment in the dust band and one in the control became vacant after 8 wk and data were missing from these apartments after 8 wk. At 12 wk, bed bugs were not found from two apartments in the dust band group and two apartments in the IPM group. All other apartments still had bed bugs based on interceptor counts.

Two researchers serviced each apartment during each visit. Their service time was recorded from wk 0 to 8. The average time (mean \pm SEM) spent in each unit during the initial treatment was significantly greater ($F = 5.6$; $df = 1, 14$; $P = 0.03$) for IPM treatments (43 ± 6 min) compared with dust band treatments (28 ± 4 min) (Fig. 6). The time in the control was not available because PMPs did not treat the apartments at the time when dust band and IPM treatments were implemented. During the 2- and 4-wk inspections, significantly more time was spent in the

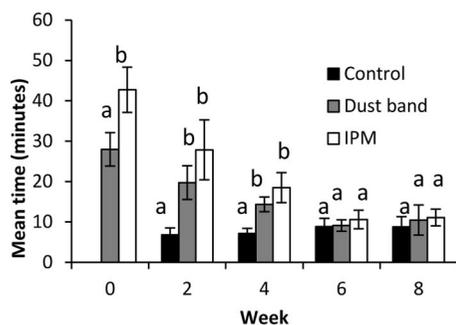


Fig. 6. Service time spent per apartment (mean \pm SEM). Two researchers serviced each apartment during each visit. Bars of the same time period with different letters indicate significant differences (ANOVA, $P < 0.05$).

dust band and IPM treatment groups than in the control group. There were no significant differences in treatment times between dust band and IPM at wk 2–8 ($P > 0.05$).

In the second field experiment where the control apartments were left untreated and no interceptors were installed for 4 wk, the bed bug counts (mean \pm SEM) increased from 8.3 ± 2.3 to 39.8 ± 22.4 (381% increase) over a 6-wk period. The bed bug count (mean \pm SEM) in the dust band plus Interceptor group changed from 4.3 ± 1.3 to 3.6 ± 1.9 (16% decrease). An average of 8.5 ± 3.9 bed bugs was trapped because of extra days (4 wk) of interceptor placement compared with the control.

Discussion

The laboratory experiment showed that bed bugs did not avoid cyfluthrin-treated fabric. Once bed bugs crossed the treated fabric, 99% of them died within 5 d. These findings are corroborated by the results of the field study. It is also interesting to note that in the control, bed bugs that fell below the plastic bands suffered significantly higher mortality than those that remained on the top of the wooden rod after 5 d. This suggests that bed bugs that rest on smooth exposed areas without a harborage die faster than those with access to a harborage. Wang et al. (2010) reported 98% mortality of the bugs trapped in interceptors installed under furniture legs during biweekly inspections. Therefore, installing interceptors under furniture legs and insecticide dust treated bands on furniture legs are effective procedures for reducing bed bug numbers.

The dust band treatment may substantially reduce the amount of insecticide used for controlling bed bugs by saving the need for perimeter dust applications. The dust bands can be easily removed and any dust dislodged from the bands will be confined inside the interceptors, thus minimizing the amount of residues left in the environment. However, applying cyfluthrin dust to furniture legs is a deviation from the current label directions and cannot be used by commercial applicators without an appropriate label change. Cyfluthrin dust was selected in this study because it is known to be highly effective against pyrethroid insecticide resistant bed bugs (Romero et al. 2009). An alternative to cyfluthrin dust is diatomaceous earth, which acts slower than cyfluthrin, but is equally effective (Romero et al. 2009) and can be applied as a dust band without deviating from label use directions. The effectiveness of diatomaceous earth treated bands need to be evaluated under field conditions.

The IPM treatment required more time than the dust band treatment during the initial treatments. This was because of the extra nonchemical procedures involved in the IPM treatment. The two treatments required a similar amount of time to perform the follow-up inspections and treatments. At 4 wk after the initial treatments, most apartments in the dust band and IPM group no longer needed retreatments.

The three treatment groups required an average 9–11 min per apartment per visit by using a two-person team for inspecting the interceptors, conducting visual inspections, or both.

Three apartments in the dust band and IPM groups still had ≥ 10 bed bugs at 12 wk after initial treatment. Two of these apartments were severely cluttered, which greatly hindered the control efforts. The beds were touching the walls and blankets were often found touching the floor, thus creating “bridges” and allowing bed bugs to bypass the insecticide dust treated bands. Residents did not launder bed linens regularly (i.e., weekly) as instructed. The third apartment was next to a heavily infested apartment that was untreated. It is very likely that bed bugs from the heavily infested unit provided a constant influx of bed bugs into the neighboring units, including the test apartment (Wang et al. 2010). Treating the neighboring infested units and improving resident cooperation will help achieve higher bed bug reduction than that reported here.

In the second field experiment, where interceptors were removed for 4 wk in the control apartments, mean bed bug numbers increased by 381% in a 6-wk period. In comparison, apartments treated with interceptors and cyfluthrin dust bands had slightly reduced number of bed bugs after 6 wk. The results show that placing interceptors under furniture legs and dust bands around furniture legs can keep bed bug populations at low levels, but will not eliminate the bed bugs completely. To eliminate an infestation, multiple treatment methods should be employed. It should be noted that four of the “interceptors plus dust bands” apartments were treated with 1% cyfluthrin dust around perimeters in Field study I. We recorded the biweekly bed bug counts before the start of the Field study II. During the 4-wk period before the Field study II, the mean number of bed bugs reduced by 66 and 61% in the apartments with dust application around perimeter and those without dust treatment, respectively. Therefore, we assumed the cyfluthrin dust from Field study I had no significant effect on the second experiment.

This study was limited by the small number of test apartments available in the building, large within treatment variances in the numbers of bed bugs at the beginning of the study, and the various levels of clutter and resident cooperation. It is extremely challenging to find large numbers of apartments with homogeneous background data. More samples will help increase the power for detecting any differences between the treatments. Yet, our results show that 1) both dust band and IPM resulted in significant bed bug reduction after 12 wk, 2) installing dust bands and interceptors was able to suppress bed bug population growth, and 3) low level bed bug populations grew

rapidly when left unmonitored or untreated. In conclusion, applying insecticide dust to furniture legs is an effective dust application technique. It is most effective when used in conjunction with intercepting devices and other nonchemical and chemical procedures for eliminating bed bugs that are already on furniture. Eliminating alternate pathways onto beds and furniture by tucking in linens, or pulling furniture away from walls, can increase the effectiveness of interceptors and dust bands on the legs of furniture.

Acknowledgments

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