Efficacy of Bed Bug Control Products in Lab Bioassays: Do They Make It Past the Starting Gate?

Robin G. Todd

The question of the effectiveness of products registered by EPA for the control of bed bugs is relevant, given the increasing prevalence of this pest and the difficulty in controlling them. Samples of most such products were tested against a laboratory strain of bed bugs at Insect Control & Research (ICR, near Baltimore, MD) under nearly optimal conditions. The samples were either purchased by ICR or donated by pesticide companies.

Products Tested

Residual Sprays and Dusts:

- D-Force (0.06% deltamethrin pressurized spray), Waterbury Co., Independence, LA
- Intruder (0.1% cyfluthrin. 0.05% pyrethrins, 1% piperonyl butoxide pressurized spray), Waterbury Co., Independence, LA
- Demand (9.7% lambda-cyahalothrin pressurized spray), Syngenta Professional Products, Greensboro, NC
- Suspend (0.5% permethrin microcrystal suspension), Bayer Crop Science, Research Triangle Park, NC
- Permacide (0.5% permethrin trigger spray emulsion) by Summit Chemical Co., Baltimore
- Delta Dust (0.05% deltamethrin dust), Bayer Crop Science, Research Triangle Park, NC
- Drione Insecticide (1% pyrethrins 10% piperonyl butoxide, 40% silica gel dust), Bayer Crop Science, Research Triangle Park, NC
- Gentrol Aerosol (0.36% hydroprene), WellMark, Schaumburg, IL
- Gentrol Concentrate (9% hydroprene), WellMark, Schaumburg, IL

Contact Sprays and Dusts:

- PT 565 Plus XLO (0.25% pyrethrins, 0.25% d-tran allethrin, 1% piperonyl butoxide, 1% MGK 264 pressurized spray), Whitmire Micro-Gen, St. Louis
- CB 80 EXTRA (0.5% pyrethrins pressurized spray) by Waterbury Co., Independence, LA
- Steri-Fab (0.22% d-phenothrin, 0.11% didecyl dimethyl ammonium chloride, 0.076% N-alkyl dimethyl benzyl ammonium chloride trigger spray), Noble Pine, Yonkers, NY
- NIC 325 (limestone dust), ACM-Texas, Fort Collins, CO

Physical Confinement:

- CleanAir Allergy Relief Mattress Protector, Philmont Manufacturing Co.

All products were tested against susceptible bed bugs, *Cimex lecularius* L., from the ICR colony. This colony was donated to ICR by USDA Gainesville, FL, in 1983. In all tests, 5 replicates of 10 adult bed bugs were used, except where nymphs were used, as noted.

Test Methods

Application rates were based on label rates, but if none were provided, application was made until the substrates were slightly damp (the dust products all had specified label rates): see Figs. 1, 3, and 13. The two Gentrol products were applied at three times the label rate.

Residual Products

The residual insecticides were applied by spraying or dusting sections of plywood (1.25 × 1.25 in) or mattress covering (1.25 × 2 in. folded in half), depending on where the product could be used, according to the label. The dusts were applied by sprinkling with thumb and forefinger. Twenty-seven days later, adult bed bugs were exposed to the treated substrates in 0.5-L plastic containers. Each container had a second, untreated substrate as harborage for the bed bugs if the treatment was repellent. Mortality was recorded at +24 h.

The two Gentrol products were applied to both sides of 5 × 10 cm strips of filter paper. The application rates for the aerosol were ~0.003195

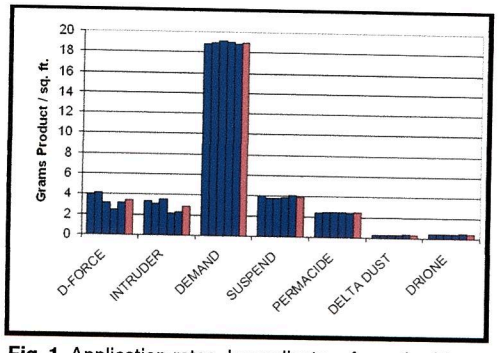

Fig. 1. Application rates, by replicate, of pyrethroid-based residual products on wood.

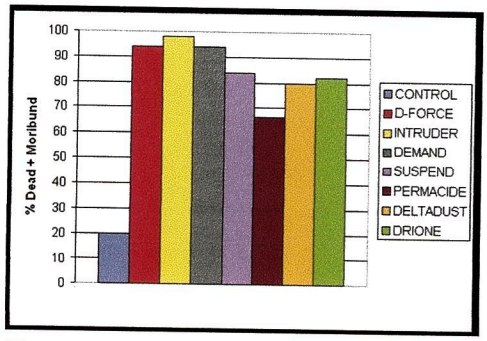

Fig. 2. Mortality of bed bugs after 24-h exposure to residual pyrethroid treatments on wood.

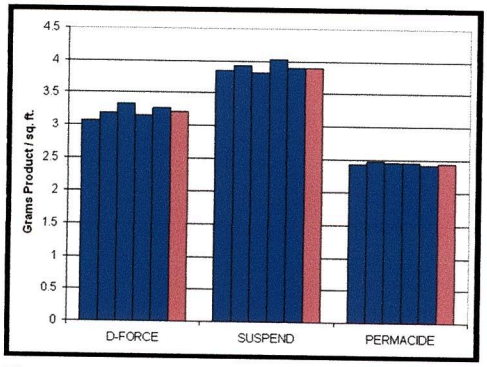

Fig. 3. Application rates, by replicate, of pyrethroid-based residual products on cloth.

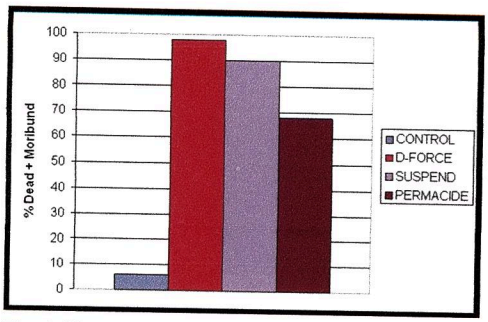

Fig. 4. Mortality of bed bugs after 24-h exposure to residual pyrethroid treatments on cloth.

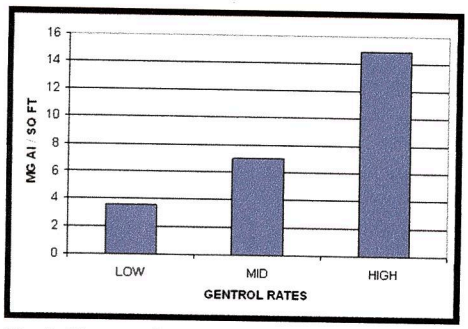

Fig. 5. Mean application rates for Gentrol concentrate.

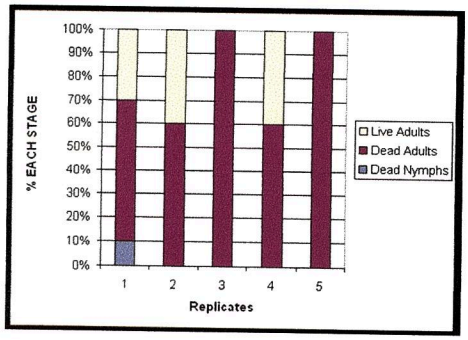

Fig. 6. Dead nymphs, dead and live adults after exposure to low-rate Gentrol concentrate.

g AI/ft², 0.00524 g AI/ft², and 0.00961 g AI/ft² (label rate is only given for the aerosol product; it is 0.00136 g AI/ft²). The applications rates for the concentrate were 0.00358 g AI/ft², 0.00669 g AI/ft²., and 0.01487 g AI/ft². These rates are shown in Figs. 5 and 9. These strips were then inserted into glass vials and 10 third instars were released onto them. The vial lids, with their tops cut off, were then screwed down over pieces of cotton to secure the nymphs. The nymphs were provided with weekly blood meals until all (treated and controls) had either died or molted into adults (7 wk).

Contact Products

Insecticides were sprayed from a distance of 18 in. at 1-L containers containing bed bugs sheltering inside 2 × 1.25 inch folded sections of mattress covering. Treated and control bed bugs were observed for flushing and knockdown at +15 min, and for mortality at + 24 h. The NIC product was applied by a power puffer, after which daily mortality readings were taken for 5 d.

Confinement

The mattress cover was cut into ~1 × 1 in. sections. The lids of 7 × 2 cm glass vials were cut down

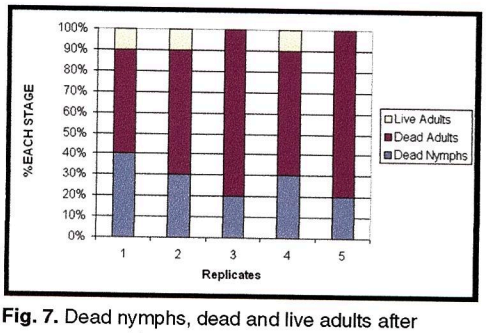

Fig. 7. Dead nymphs, dead and live adults after exposure to mid-rate Gentrol concentrate.

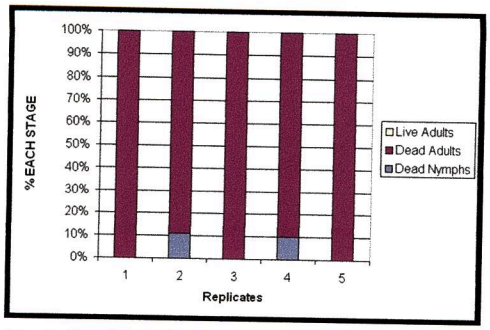

Fig. 8. Dead nymphs, dead and live adults after exposure to high-rate treatment with Gentrol concentrate.

to leave each as a threaded ring with no top. One starved bed bug was placed in each of 20 vials, with a strip of filter paper for them to crawl on. The mattress cover sections were then secured over the mouths of the vials by screwing down the cut-down lids. Twenty adults, 20 second instars, and 20 fourth instars were set up in this manner. The vials were then inverted over the forearms of a volunteer (the author), and the bed bugs were allowed 6 min in which to feed. Feeding was recorded based on visible uptake of blood because I could not feel the bites. Any bed bugs that did not feed were given the opportunity to feed using the same procedure, but with porous screen sections replacing the mattress cover sections. This step confirmed that any bed bugs that did not feed through the mattress cover were actually able and willing to feed.

Results

Residual Products

Pyrethoid Products. All products gave >60% 24-h mortality after aging for 27 d on wood and on cloth. There were no statistically significant differences for cloth, but Permacide gave significantly lower mortality on wood (ANOVA at $p \leq 0.05$). The application rate for Demand greatly exceeded the others (Fig. 1), but it did not give the highest mortality; this was achieved by Intruder on wood and D-Force on cloth. The results are summarized in Figs. 1–4.

Gentrol Products. All bed bugs among the control replicates successfully molted into adults by 5 wk and survived until the study ended at 7 wk. There was no evidence that Gentrol delayed molting; all surviving treated nymphs had molted into adults by 4 or 5 wk. At the end of the study,

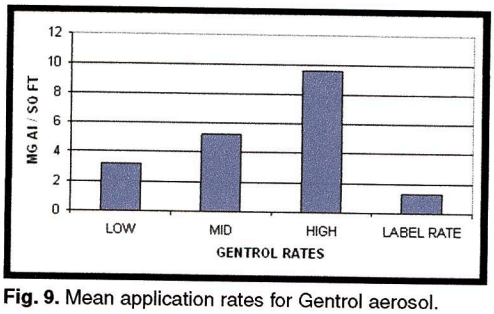

Fig. 9. Mean application rates for Gentrol aerosol.

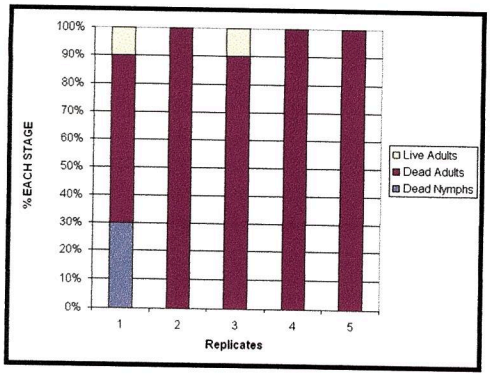

Fig. 10. Dead nymphs, dead and live adults after exposure to low-rate treatment with Gentrol aerosol.

72–98% of nymphs had molted into adults. There was, however, considerable (66–100%) mortality among these adults. Many of these and some of the nymphs had, apparently, ruptured guts (either haeomocoel and legs being filled with blood, or blood oozing out of the gut at the juncture of the thorax and abdomen). Neither Gentrol product completely prevented development into adults, but the early death of many adults may aid in control. Some of the adults had produced F1 progeny; early instars were present in at least one replicate of the low- and mid-rate concentrate treatments and in one replicate of the mid-rate aerosol treatment (Table 1). There was little evidence of a dose response, except for live adults, among the concentrate treatments. The Gentrol results are summarized in Figs. 5–12.

Direct Contact Products

Application rates for the three pyrethroid products are shown in Fig. 13. None of these products exhibited significant flushing action; more bed bugs were flushed from the controls than from the 565 Plus or the Steri-Fab treated shelters, indicating normal behavior rather than chemically-induced flushing. Of the three, CB 80 provided the best flushing action (40%). 565 Plus provided 100% knockdown, CB 80-95%, and Steri-Fab produced just <60%. 565 Plus and CB 80 caused 100% mortality at +24 h, and Steri-Fab gave 96% (100% if moribund individuals were included). The data for these three products are summarized in Figs. 14–16.

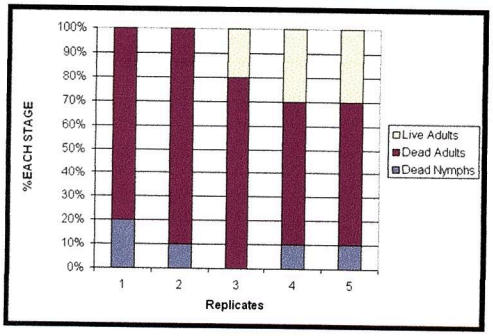

Fig. 11. Dead nymphs, dead and live adults after exposure to mid-rate treatment with Gentrol aerosol.

Table 1. Development of F1 progeny from bed bugs originating as third instars.

Group		Replicates				
		1	2	3	4	5
Control		+	+	+	+	+
Concentrate	Low	+	+	–	–	+
	Mid	–	+	–	–	–
	High	–	–	–	–	–
Aerosol	Low	–	–	–	–	–
	Mid	+	–	–	–	–

NIC was applied at 0.453–0.461 g/ft²; the treated insects had visible white powder residues on their abdomens. Mortality averaged only 20% after 5 d of exposure (0–50% mortality in the replicates).

Mattress Protector

Bed bugs were unable to feed through the mattress protector material; however, bed bugs did not readily feed through the porous screen. Only 9 adults fed; 18 of the second instars, and 12 of the fourth instars fed. The adults were held for an additional 29 d and given another opportunity to feed through the mattress protector (none fed) and the porous screen (3 of 7 fed). It is interesting to note the disparity between the adults and the nymphs in their willingness to feed; we have seen this repeated in subsequent studies.

Conclusions

The pyrethroid-based products gave good control at +27 d on two substrates, but we did not get 100% kill. Although the Gentrol products failed to prevent development of most nymphs to adults and some F1

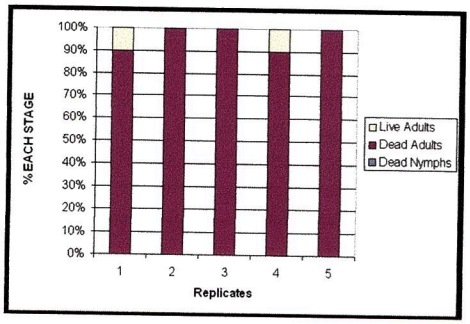

Fig. 12. Dead nymphs, dead and live adults after exposure to high-rate treatment with Gentrol aerosol.

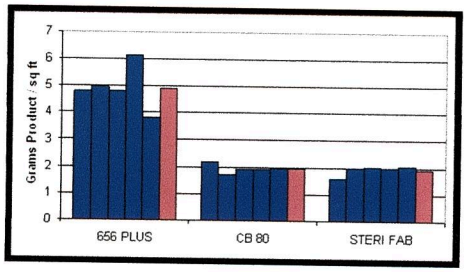

Fig. 13. Application rates, by replicate, of pyrethroid-based contact products.

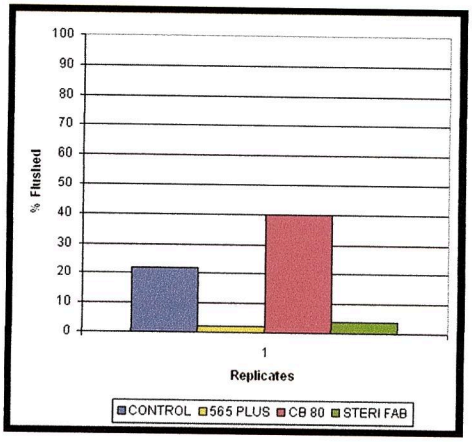

Fig. 14. Mean flushing rates for pyrethroid-based contact products.

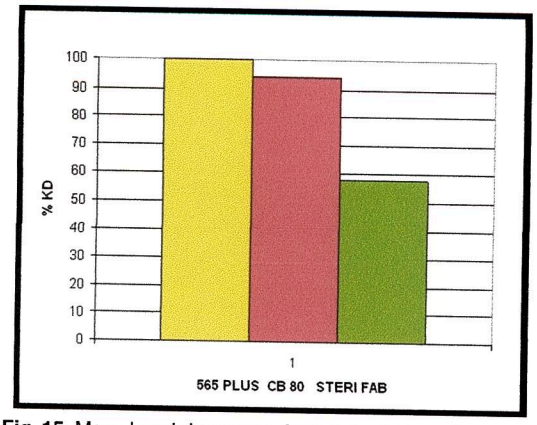

Fig. 15. Mean knockdown rates for pyrethroid-based contact products (there was no knockdown among the controls).

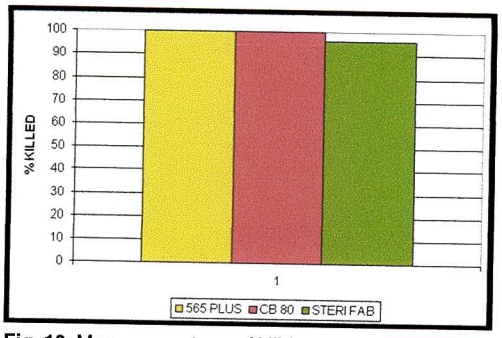

Fig. 16. Mean percentage of kill for pyrethroid-based contact products (there was no knockdown among the controls).

progeny were produced, they did cause substantial adult mortality.

The pyrethroid-based contact products gave little if any flushing action, fair knockdown, and good kill. The NIC product was not effective. The CleanAir mattress protector prevented biting.

Acknowledgments

I wish to acknowledge Jim Sargent of Copesan for the idea of testing a mattress protector and for funding this part of the study. I wish to thank the following ICR staffers for their able assistance, without which this study would have been impossible: Timothy Foard, Bill Gaynor, Bob Kilbourn, Jennifer Russell, John Sharpe, Nick Spero, and Gloria Stevens. I also thank Jonathan Cohen of Summit Chemical, Richard Goldman of Noble Pine, and Mac McCreless, ACM Texas, for providing samples.

Robin G. Todd, PhD BCE Director Insect Control & Research, Inc. 1330 Dillon Heights Avenue, Baltimore, MD 21228-1199.

Foraging and Communication Ecology of bed bugs, *Cimex lectularius* L. (Hemiptera: Cimicidae)

E. D. Siljander

How bed bugs find their hosts and each other is among the least understood aspects of bed bug biology. This has long been identified as a problem (Johnson 1942, Usinger 1966), but despite the efforts of many researchers, relatively little conclusive information has been produced. Much of this can be attributed to the fact that most research on bed bug foraging and communication ecology was done more than 40 years ago, when analytical methods were not as sophisticated as they are today. This contributed to many conflicting results between and within studies. Some studies concluded that bed bugs could not detect a human beyond 3–4 cm away (Kemper 1929, Rivnay 1932), whereas another concluded that they could orient to a human from a distance of 150 cm (Marx 1955). Moreover, some studies claim that bed bugs will aggregate under paper previously exposed to other bugs (Marx 1955, Levinson and Bar Ilan 1971), whereas others claim that they show no preference (Usinger 1966, Aboul-Nasr and Erakey 1968). Taking all the literature on bed bug foraging and communication ecology into account, there is little agreement on which stimuli affect their behavior.

Foraging Ecology

Haematophagous insects can use body temperature, moisture, host-derived volatiles, carbon dioxide, (CO_2) and visual cues to locate a host (Takken 1991). Studies of bed bug host location have tested for attraction to heat, humidity, blood, carbon dioxide, muscle and subcutaneous tissue, liver, bile, skin, hair, perspiration, sebum, and ceru-