Insecticide-Resistant Bed Bugs: IMPLICATIONS FOR THE INDUSTRY

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Last year, researchers at the University of Kentucky reported high levels of insecticide resistance in field-collected bed bugs. Details of the study are discussed in this article — along with sobering implications for the pest management industry.

All photos are courtesy of M.F. Potter

The rapid resurgence of the bed bug, *Cimex lectularius* L., is perhaps the hottest pest management topic of the day. No pest in a generation has had so swift and sweeping an effect on the quality of people's lives. Pest managers, in turn, have been searching for a solution, which has primarily meant the application of available insecticides.

Bed bugs by their nature are challenging to control. They can hide almost anywhere and escape detection by even the most experienced inspector. Re-introduction on infested items, or from adjoining living units, can further compromise treatment success. Last year, however, while working with a pest control firm in Cincinnati (Permakil), we noticed that some apartment infestations were especially resilient, surviving direct spray applications with a widely-used pyrethroid insecticide. This prompted us to investigate whether the bugs had become resistant to this important chemical class, and if the phenomenon was more widespread.

STUDY METHODS. With the help of pest control firms, bed bugs were collected from infested buildings across the United States. Four different colonies were established from separate apartment buildings located in Lexington, Ky., and Cincinnati. Other field collections were made from bed bug-infested dwellings in Kissimmee, Fla.; Vienna, Va.; Smithtown, N.Y.; Dover, N.J.; Worcester, Mass.; Kalamazoo, Southfield, and Bloomfield Hills, Mich.; as well as two collections from different floors of the same apartment building in Los Angeles. All collections were made before treatment and with no prior

Top left photo: Resistance is only *one* possible reason why infestations may be hard to eradicate (concealment being another). This bug was hiding in a patient's wheelchair. Top right photo: A shipment of bed bugs from New Jersey submitted by Cooper Pest Solutions. Bottom photo: Resistance might be a factor if large numbers of bed bugs persist on previously treated surfaces.

knowledge of whether the bed bug population might be susceptible or resistant to insecticides. For comparison, we also tested the susceptibility of two long-maintained laboratory populations that had never been exposed to pyrethroids — one collected more than 30 years ago from Ft. Dix, N.J., and another collected more than 20 years ago from Gainesville, Fla.

In order to have enough bed bugs to test at different insecticide doses, some field collections were reared initially in the laboratory using an artificial feeder. Colonies were kept in screened jars and fed warmed chicken blood through a thinly stretched "parafilm" membrane to simulate feeding through skin.

Susceptibility of each population was evaluated by confining individual bed bugs on pyrethroid-treated filter paper. Adults or third- to fifth-instar nymphs were used, depending on the experiment and availability of insects. Deltamethrin and lambda cyhalothrin — two of the most popular and potent pyrethroid active ingredients — were evaluated at varying concentrations and the resultant mortality determined after 24 hours of exposure.

LOCATION AND SUSCEPTIBILITY STATUS OF 16 BED BUG FIELD POPULATIONS

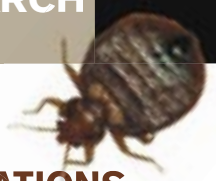
RESULTS. There was a dramatic difference in susceptibility between bed bugs maintained several years in the laboratory and most field-collected populations. The Ft. Dix, N.J., lab strain that had never been exposed to pyrethroids suffered 100 percent mortality at concentrations well below label rates of both deltamethrin and lambda cyhalothrin. In contrast, the four field populations from Kentucky and Ohio were essentially "im-

mune" to both pyrethroids — even when confined on fresh residues from dosages *200-300 times higher* than the recommended label rates. Little mortality likewise occurred when these same field populations were sprayed directly with commercial formulations of Suspend SC and Demand CS, rather than being confined on previously treated surfaces. Interestingly, when bed bugs from one of the pyrethroid-resistant field strains were allowed to mate with those from the susceptible Ft. Dix laboratory strain, the offspring exhibited intermediate resistance of a level likely to result in treatment failures — suggesting that the trait was genetically based.

Further testing of third-to-fifth instar nymphs from 16 different field populations indicated that pyrethroid resistance in bed bugs, while not universal, may be widespread (*see accompanying map and table on pages 44 and 48*). Using a "discriminating" dose equivalent to 10 times the labeled rate of deltamethrin (0.6 percent), 14 of 16 populations collected in Kentucky, Ohio, Michigan, New York, Massachusetts, Virginia, Florida and California were resistant (0 percent mortality), one field population from New Jersey was deemed "intermediate" (45 percent mortality), and one of the two populations collected from the same building in California was relatively susceptible (100 percent mortality). Finding susceptible and resistant bed bug populations in the same building suggests there may have been separate introductions, or perhaps rapid development of resistance from the same initial population.

RESISTANCE SO SOON? The findings of this study are worrisome but not unexpected. Like cockroaches and many other pests, bed bugs have a history of developing resistance to insecticides. By the late 1940s and '50s, some bed bug populations were already becoming resistant to DDT, the "wonder" insecticide often credited with all but wiping out the pest. How did 21st century bed bugs develop resistance to pyrethroids so soon? The reason may involve a phenomenon known as "cross resistance." When pests become resistant to one class of insecticide, they soon can resist another having a similar mode of action. Cross-resistance to DDT and pyrethroids has been demonstrated in such pests as houseflies and mosquitoes, and could explain why some bed bug populations in this country became "immune" to modern-day insecticides so quickly *(see related story "If We Just Had DDT" on page 50)*.

Another factor hastening pyrethroid resistance in bed bugs may have been the "selection pressure" they were under before arriving here from other locales. International travel is one of the most common hypothesis for their resurgence, and observations of pest managers support this. When bed bugs began reappearing in the United States in the late 1990s, a high percentage of the early infestations involved people from other areas of the world, where the bugs have long been a nuisance. Although DDT was banned in the U.S. in 1972, heavy usage continued in other countries to control disease-carrying mosquitoes and bed bugs. For more than 20 years, pyrethroids also were used in these locales as residual sprays and incorporated into bed nets to combat malaria and bed bugs. Consequently, infestations in the U.S. (and perhaps Europe and Australia) could have been exposed to prolonged and intense selection pressure from both DDT *and* pyrethroids — a "doomsday" scenario for hastening resistance. Pyrethroid resistance in bed bugs also recently has been reported in Africa and the United Kingdom, suggesting



MORTALITY OF 18 BED BUG POPULATIONS

Mortality of two laboratory and 16 field-collected bed bug populations (third-to-fifth instar nymphs) exposed 24 hours to an elevated dose (13mg/cm^2) of technical grade (99% active ingredient) deltamethrin. There was no mortality in untreated insects from these populations.

POPULATION	ORIGIN	% MORTALITY
Laboratory 1	Ft. Dix, NJ	100
Laboratory 2	Gainesville, FL	100
LA1	Los Angeles, CA	100
DOV-1	Dover, NJ	45
LA2	Los Angeles, CA	0
KIS1	Kissimmee, FL	0
LEX1	Lexington, KY	0
CIN1	Cincinnati, OH	0
CIN2	Cincinnati, OH	0
CIN3	Cincinnati, OH	0
CIN4	Cincinnati, OH	0
CIN5	Cincinnati, OH	0
VIN1	Vienna, VA	0
WOR-1	Worcester, MA	0
KAL-1	Kalamazoo, MI	0
BLO-1	Bloomfield Hills, MI	0
SOU-1	Southfield, MI	0
SMI-1	Smithtown, NY	0

this soon may become a global issue.

GOT RESISTANCE? There is no way to predict where resistant bed bugs will be encountered. Our "incidence" map (*see page 44*) is simply a reflection of where we happened to receive samples from cooperating pest control firms. Moreover, these insects are adept hitchhikers; the infestation in an account could have originated from across the street — or across the ocean.

Is there a way to determine if your clients' bed bugs are pyrethroid resistant? Resistance screening as reported in this study is time consuming and a non-option for most pest managers. Concern might be warranted if substantial numbers of bed bugs continue to reside on previously treated surfaces, especially after multiple and thorough applications.

IMPLICATIONS FOR THE INDUSTRY. As previously noted, insecticide resistance in the bed bug is not a new phenomenon. What is so worrisome this time is that we have few alternatives if pyrethroid resistance becomes rampant. The regulatory restriction of organochlorine, organophosphate and carbamate insecticides — some of which controlled bed bugs with a single application — has diminished chemical options for treating bed bugs. These restrictions could come back to haunt us, underscoring what can happen when pests resurface after entire classes of insecticide are removed from the market.

History has shown that it is hard to efficiently eliminate bed bugs without a residually potent insecticide — one that keeps killing long after the spray deposit has dried. Prior to the availability of DDT in the late 1940s, bed bug products generally had poor residual action and had to be sprayed directly on the insects to kill them. Many such mixtures were available, most of them formulated

as oil-based sprays. Alcohol or alcohol-based solutions were also used years ago as non-residual bed bug killers. Insecticides having a "watery base" reportedly were less effective as contact killers, which could explain why some of today's products, especially those formulated as emulsifiable concentrates or pressurized aerosols, seem to perform better when the bugs are sprayed directly. Sprays lacking in residual effect usually require repeated applications since some bed bugs remain hidden during treatment. Subsequent applications also are needed to kill nymphs emerging from eggs, or bugs reintroduced into the building.

Few insecticides today which are not pyrethroids have residual effectiveness against bed bugs. Phantom (chlorfenapyr) is one option, although preliminary studies suggest it is relatively slow acting, often taking more than a week to kill continuously exposed individuals. Insect growth regulators such as Gentrol also are slow-acting and are not meant to be used as stand-alone insecticides. Sterifab and Bedlam provide rapid kill of both susceptible and resistant bed bugs when insects are sprayed directly, but have diminished effects after drying on a surface — especially against resistant populations since both products contain a pyrethroid (phenothrin) *(see "Killing Them Softly: Battling Bed Bugs in Sensitive Places," PCT January 2007)*. A similar effect has been noted in preliminary experiments with the pyrethrum-containing emulsifiable concentrate formulation of Kicker, applied alone or in combination with a pyrethroid. Dust formulations containing silica gel or diatomaceous earth kill pyrethroid-resistant bed bugs, but the utility of dusts is limited by where they can be legally or prudently applied.

In conclusion, bed bug management is expected to remain quite a challenge until there is a residually potent insecticide with a similarly permissive label. Until then we will need to work with the products we have, including such tools as steamers, vacuums, encasements, laundering, disposal and fumigation. Educating the public about bed bugs, and how infestations arise and can be prevented, also will be essential.

Finally, while results of this study suggest that pyrethroid resistance in bed bugs may be widespread, many firms still report satisfactory results much of the time with these materials. Technicians and managers should remember that there are reasons other than resistance as to why infestations may be hard to eradicate — including reintroduction of infested items, migration from adjoining living units, clutter, and the ability of the bed bug to hide almost anywhere. Let's hope that in the future the arsenal of effective bed bug products rivals that for termites.

Alvaro Romero is a Ph.D. student at the University of Kentucky. Michael F. Potter and Kenneth F. Haynes are entomology professors at the same institution.

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IF WE JUST HAD DDT...

Many believe that if DDT were available today it would solve our current bed bug problem as it did years ago — but not necessarily. When adult bed bugs from a pyrethroid-susceptible laboratory colony were confined on surfaces treated with 5% DDT (the previous labeled dose), most died within a few days. Field-collected bed bugs, however, were a different story. Three of the four pyrethroid-resistant populations we tested exhibited minimal mortality after *five continuous days of exposure* — suggesting that bed bug resistance to DDT may be common today, as was becoming the case a half-century ago when the pest was vanishing from this country.

DDT VS. 21ST CENTURY BED BUGS

Bed Bug Population	Mortality after 5 days exposure to DDT
Laboratory (pyrethroid suseptible)	95%
WOR-1 (pyrethroid resistant)	100%
DOV-1 (pyrethroid resistant)	30%
CIN-1 (pyrethroid resistant)	10%
LEX-1 (pyrethroid resistant)	5%

References

Romero, A., M.F. Potter, D.A. Potter and K.F. Haynes. 2007. Insecticide resistance in the bed bug: a factor in the pest's sudden resurgence? J. Med. Entomol. 44 (2):175-178.

Myamba, J, C.A. Maxwell, A. Asidi and C.F. Curtis. 2002. Pyrethroid resistance in tropical bed bugs, *Cimex hemipterus*, associated with use of treated bednets. Med. and Vet. Entomol. 16, 448-451

Boase, C.J., G. Small, and R. Naylor. 2006. Interim report on insecticide susceptibility status of UK bedbugs. Professional Pest Controller. Summer 2006:6-7.

Karunaratne, S.H.P.P., B.T. Damayanthi, M.H.J. Fareena, V. Imbuldeniya, and J. Hemingway. 2007. Insecticide resistance in the tropical bed bug *Cimex hemipterus*. Pestic. Bochem. Physiol. 88, 102-107.