Proceedings of the Seventh International Conference on Urban Pests
William H Robinson and Ana Eugênia de Carvalho Campos (editors) 2011
Printed by Instituto Biológico, São Paulo, SP. Brazil.

USE OF HEAT, VOLATILE INSECTICIDE, AND MONITORING TOOLS TO CONTROL BED BUGS (HETEROPTERA: CIMICIDAE)

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Abstract Detection and control of bed bugs can be challenging and alternative control methods are needed. Among new bed bug management techniques localized heat treatments, use of volatile insecticides and heat combination, and new detecting techniques using electronic sensors. However, management of bed bug infestations may continue to be inefficient and expensive until more innovative techniques are developed and integrated into the pest control toolbox.
Key Words *Cimex lectularius,* heat treatment, DDVP, insecticides, detection.

INTRODUCTION

Bed bugs, *Cimex lectularius* L., have lived with humans for > 3,500 years (Panagiotakopulu and Buckland 1999) but a resurgence of bed bugs in Western countries in recent years has cause great concern (Harlan et al., 2008, Pinto et al., 2007). Detection and control of bed bugs can be challenging (Cooper and Harlan, 2004), and bed bugs have shown resistance to many insecticide products (Moore and Miller, 2006; Romero et al., 2007). Therefore, alternative control methods for bed bug treatments are necessary in order to control infestations. Among new techniques being used or tested for use in bed bug management are heat treatments and volatile insecticides, used in the control of pest populations, and monitoring devices that allow detection of small bed bug populations before they become a problem and can be detected by simple visual inspection.

HEAT TREATMENT

Given the difficulties encountered in the use of insecticides for control of bed bugs, physical control methods can useful in managing bed bug infestations. Heat treatment of a whole room or building is currently used for control of bed bugs (Pinto et al., 2007, Kells, 2006) and other insects such as storage pests (Tang et al., 2007).

Temperatures between 44 and 45°C (Doggett et al., 2006) are known as lethal to bed bugs, while lower temperatures can be detrimental to bed bug symbionts, and consequently prevent bed bug reproduction (Chang, 1974). Laboratory results confirm that temperature as low as 41°C can kill bed bug adults if exposures are long enough. Furthermore, because temperatures above 41°C are lethal to bed bug adults, as the temperature increases above this threshold, accumulated heat stress increases and bed bugs mortality increases. The estimated activation energy (E_A) needed to kill bed bugs is around 480 to 490 kJ/mol (Pereira et al., 2009), and similar to those obtained for other non heat-tolerant insects, suggesting that bed bugs are not especially heat resistant.

The use of solar radiation seems like a good and cheap source of heat for bed bug control in furniture, but in tests in Australia it did not provide adequate bed bug control in mattresses because the insects escaped high temperature areas (Doggett et al., 2006). Besides the energy requirements, cost of equipment, treatment duration, and other are common problems in using heat for control of bed bugs. However, recent studies with localized heat treatments have produced adequate results in situations where infestations are confined (Pereira et al., 2009).

Temperatures needed to kill bed bugs are lower than those that cause damage to furniture and other materials, so the use of a localized heat treatment for bed bugs can be economical and fairly simple to set up. The set up uses oil-filled electrical space heaters (Pelonis Appliances Inc. Grand Prairie, TX, model HO-2018; or DeLonghi, Shelton, CT, model EW6507L) and box fans (e.g., 50.8 cm diam., Lasko, West Chester, PA) to create a convection oven inside a box built out of 6 polystyrene sheathing board insulation (122 X 224 cm with 5 cm thickness) connected with common masking tape (Figure 1). Temperatures are monitored with outdoor/indoor consumer digital thermometers or other temperature monitoring equipment. The room furniture is grouped at the center of the room. Oil-filled heaters are placed on the floor around the furniture and box fans positioned so that air is blown through the radiator of the heaters. The treatment chamber created around the furniture with the insulation boards contains the heat around the furniture being treated (Pereira et al., 2009). Despite getting temperatures well above the lethal levels for bed bugs within the treatment chamber, the insulation boards guarantee that the room temperature stays at comfortable levels for human activity. This allows the application of residual pesticide to the baseboard and other potential resting areas for bed bugs.

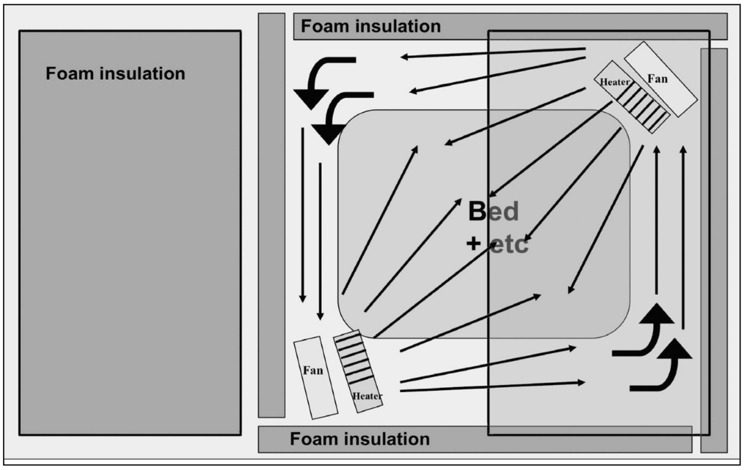

Figure 1. Top view of heat chamber set-up for bed bug control showing furniture placed at center of the chamber, heater/fan combinations at opposite corners, and chamber construction using 4 insulation boards (122 X 224 cm with 5 cm thickness) as side walls and 2 boards for the chamber top. Arrows indicate air circulation.

Containment and circulation of heat around the treated material are crucial factors in an efficient heat treatment for bed bug control. When the heat is contained and circulated efficiently, the air space around the treated furniture increases rapidly and quickly immobilize the bed bugs and allows treatments to be completed in a short time (4-8 h) compared to 16 h or more required for whole-room treatments (Getty et al., 2008). Long treatment times cause major disruption in use of the treated structure, and require greater energy input. Localized heat treatment of furniture and other materials can be combined with other bed bug control methods with minimal disruption in use of the treated room.

VOLATILE INSECTICIDES

Because heat treatments can require, depending on the method used, >1 day in order to homogenize the temperature within the heat treatment area, and treatments may leave pockets of cooler air where bed bugs can survive (Doggett et al., 2006; Pereira et al., 2009), enhancement of heat treatments becomes a necessity in certain situations. Dichlorvos (2, 2-dichlorovinyl dimethyl phosphate), also known as DDVP, a volatile organophosphate once commonly used to control household insects can be used as such enhancement. Dichlorvos is formulated into resin strips, which have been shown to be effective against bed bugs in small lab tests (Potter et al., 2010). But recent results and in room applications demonstrated increase efficacy when the volatile insecticide was used with high air circulation alone or with a combination of heat and air circulation (Lenhert et al., 2011) (Figure 2).

While dichlorvos resin strips alone may take over 7 days to kill all bed bugs present in a treated room (Figure 3A), when a fan is added to provide elevated air circulation, time to reach 100% mortality decreases to 3 days. The addition of heat to increase volatilization of the DDVP decreased treatment time to only 36 h. This was due to increased pesticide volatilization of the DDVP from strips, as shown by resin strip weight loss for each treatment (Figure 3B), and the increased circulation of the pesticide (Lenhert et al., 2011).

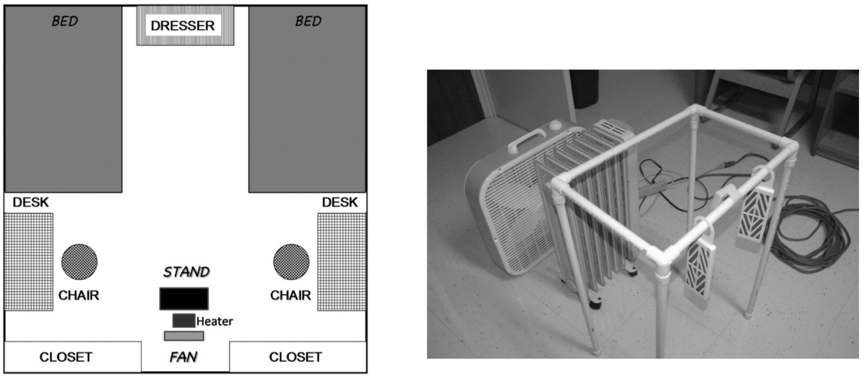

Figure 2. Drawing of dormitory room set-up for bed bug control using heat and dichlorvos strips showing placement of fan, heater, and pvc-pipe stand with dichlorvos strips. Picture of fan, heater and stand set-up.

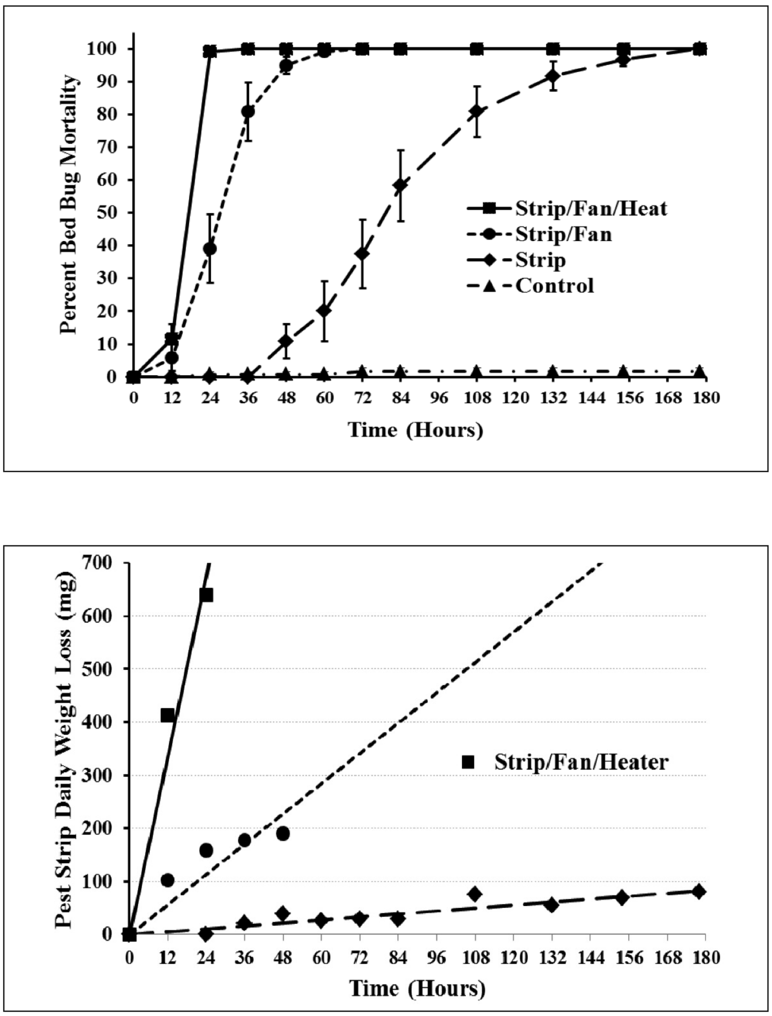

Figure 3. Top, A. Dichlorvos resin strips alone may take over 7 days to kill all bed bugs present in a treated room. Bottom, B. The addition of heat to increase volatilization of the DDVP decreased treatment time to only 36 h.

This treatment system is not designed to elevate the room temperatures to lethal levels to the bed bugs. Temperatures in rooms with heaters do not reach >36 °C at locations away from immediately in front of the heater, where the insecticide strips are placed. The increased temperature is not sufficient to have any direct effects on bed bug mortality. However, combined with the presence of the dichlorvos strip, the sublethal heat causes considerably faster bed bug mortality by increasing insecticide molecule movement speed in the air, and increasing pesticide circulation and bed bug exposure to pesticide due to increased volatilization and higher concentration of pesticide in treated rooms. High temperatures also cause an increase in insect metabolism and respiration and increased spiracular intake of the pesticide by the bed bugs.

Heat treatment with addition of dichlorvos strips provides efficient bed bug control at lower energy costs and shorter treatment time than use of heat alone. It also reduces the possibility of bed bug population spread, because the heat levels used are not enough to trigger bed bug movement away from their harborages. The treatment is also effective against eggs, which desiccate, turn brown, and fail to hatch (Lenhert et al., 2011). Use of heat and air circulation increases efficacy of dichlorvos applications for bed bug control. However, because heat increases the dichlorvos concentration in the air to levels well above those normally observed in unheated rooms, cartridge respirators should be worn by technicians exposed to dichlorvos during treatment set-up and maintenance.

MONITORING

Because bed bugs hide in cracks and crevices and other harborages, detection is very difficult, especially in early infestations (Pinto et al., 2007). Dogs have been used in the detection of hidden bed bug infestations (Cooper, 2007; Doggett, 2007; Pfiester et al., 2008), but their use is expensive. Several detectors using chemical lures and attractants have been proposed and tested (Wang et al., 2011) have been developed and some show have been shown to be very effective. However, no detector has been universally accepted in the market place.

A new type of detector has been recently proposed, which detects the movements or sounds by bed bugs and other insects (Mankin et al., 2010). The detector uses infrared sensors, microphones, and a piezoelectric sensor focused on a small area where insects can enter and move. Adult bed bugs can be detected and distinguished from other insects by the durations of infrared signals, durations of insect sound impulse patterns, and the energy levels of sound impulses. This inexpensive, polymodal-sensor instrument could be incorporated into automated detecting systems to identify bed bugs.

CONCLUSIONS

Because bed bug research had been mostly at a hiatus since the 1940's and 1950's when bed bugs were still considered serious urban pest, new technologies for management of bed bug infestations are only slowly trickling into the literature and the arsenal of pest control companies. New pesticidal active ingredients are slow to come by and new formulations of older active ingredients may not offer the best solutions for bed bug management. It may take some time until we have all the tools we need to manage bed bug infestations efficiently and inexpensively.

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