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DETECTION AND CONTROL OF BED BUGS: RECENT INNOVATION FOR BOTH

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Abstract Effective bed bug management relies on three key phases: bed bug detection, bed bug control, and bed bug monitoring. Effective bed bug detection can be an invasive and time-consuming endeavor. As such, there is a need for tools that can be used to provide pest management professionals additional information in their inspection. We present field data evaluating the performance of a lateral flow strip for bed bug detection. After a bed bug infestation is discovered, a control program is needed to eliminate bed bugs from an area. There are several products available for bed bug remediation, but one of the most effective tools available for bed bug control are insecticidal dusts. Effective as long as they remain dry and undisturbed, insecticidal dusts are a critical component of any bed bug control program. I present data on a new insecticidal dust for the pest management market, Temprid dust. Containing a pyrethroid (beta-cyfluthrin) and a butenolide (flupyradifurone), this silica-aerogel dust has been shown to be extremely effective against bed bugs and other pests.

Key words detection, inspection, control, monitoring, beta-cyfluthrin, flupyradifurone, lateral flow strip

INTRODUCTION

Bed bugs are parasitic insects that people can acquire from any location where other people are present. They can be picked up from buses, planes, hotels, and any number of other public places. People that have been infested with bed bugs often suffer from various psychological effects, ranging from paranoia, hyper vigilance, and insomnia. While bed bugs are not known to transmit disease, bed bugs can still cause significant mental trauma to people that are infested. Bed bugs are difficult to spot, adding to the difficulty of their control. Nocturnal and cryptic, these flat insects can hide in small cracks and crevices around resting areas where people and pets reside. Failure to detect infestations early can have dramatic pest management consequences as these populations can bloom if left unchecked. Proactive and early detection of bed bugs is key to effectively getting these pests under control (Cooper et al 2016).

Bed bug management revolves around bed bug detection, control, and monitoring. All three are needed to effectively manage bed bug infestations. Detection is obvious; as pest control operators need to be able to find bed bugs first before bringing control methods to bear. There are several tools available for bed bug detection, but all tools have their respective pros and cons. Human visual inspection is the most common method for bed bug detection, and many pest control companies offer visual inspection as part of their service. However, human visual inspection can falter in their detection accuracy (Wang et al. 2011), may take significant time, is labor intensive, and is often not cost effective. Pitfall traps have also been employed as bed bug detection tools. While pitfall traps can be effective in detecting bed bugs (Wang et al. 2009) and

only capture live bed bugs (thus indicating whether an infestation is active), pitfall traps require 10-14 days of continuous deployment in a customer's location to achieve actionable results. Pitfall traps can be cost effective, only costing ~$4 per trap, but can be rendered ineffective if dust and debris enter the trap, enabling trapped bed bugs to escape. Pitfall traps that do capture insects also require the identification of the trapped insect, thereby introducing an additional labor cost on behalf of the pest control operator. Bed bug sniffing canine teams are employed by some pest control companies to quickly detect bed bugs in a large inspection area, but the accuracy of which has had questionable results in the past (Cooper et al. 2014). It is important to note that canines are animals and are thus affected and influenced by the promise of rewards such as treats, play time, and attention. Canines also operate with a human handler, so the coordination of both is necessary to achieve results. Canines may operate at a high degree of detection accuracy at first, but if they feel as though they are not rewarded for their efforts, may drop in their reliability and detection accuracy (Cooper et al. 2014). One aspect of canine bed bug detection that is seldom discussed are the particularities of their use. Often pest control operators will refrain from deploying their canines in locations where pesticides have been previously used to preserve the canine's nose, and in doing so, limit their usefulness. A new detection device based on lateral flow strip technology, known in the market by the brand TruDetx, has entered the market promising detection accuracy, speed, ease of use, at a reasonable price. Lateral flow strips, traditionally used as the enabling technology behind pregnancy strips, have also been used in numerous other applications, such as detection of food contamination. However, the use of lateral flow strips for bed bug detection has not been commercialized before and is a novel use of this technology (Ko & Choe 2020).

The second step of an effective bed bug management program is control. Pest control operators need to employ effective control tactics to kill the bed bugs in their environment. Bed bug control methods vary, but this ultimately boils down to killing bed bugs in an efficient manner. Bed bug control methods range from pesticides (such as sprays and insecticidal dusts) to physical control methods, such as heat treatments. While heat treatments are typically reserved for the most extensive bed bug infestations, and as such often are the most expensive to employ, these tools are often not used for small to medium infestations (save for portable heaters used to treat small, infested items such as luggage). Heat treatments also lack residual efficacy, so they are only useful as a knockdown agent to get severe infestations under control and to a manageable level. The most used tool for bed bug infestations is the use of insecticidal sprays. Often mixed with water and applied using a canister sprayer (such as B&G), sprays can be comprised of various active ingredients; the most effective of which use combinations of active ingredients to affect bed bug mortality and reduce the likelihood of cross resistance development. In my opinion, as a former pest control operator, I believe that insecticidal dusts are the most effective tools pest control operators can use against bed bug infestations. These dusts are comprised of dustable particles (such as diatomaceous earth, silica aerogel, talcum powder, perlite, etc) and may be amended with various active ingredients. Highly versatile, these insecticidal dusts can be applied to surfaces using a variety of different application tools, ranging from traditional bulb and bellows dusters, brush dusters, and electronic dusters. Bulb and bellows dusters excel in the application of dusts into cracks, crevices, and voids, whereas brush dusters can be used for applications onto flat surfaces. Niche dusters also exist, such as pole dusters, and carpet dusters. Indeed, insecticidal dusts can be employed to treat nearly every type of surface where a pest control operator may encounter an infestation.

The final step in an effective bed bug management program is the use of bed bug monitoring tools. Bed bug monitoring tools are needed to confirm whether control methods have been effective. Management programs without effective detection will often fail to deploy control methods in the correct location. Programs without effective control will struggle to kill detected bed bugs, and programs without monitoring tools will struggle to know if the control programs they have employed have effectively eliminated the bed bugs. One of the most effective monitoring tools that pest control operators can deploy is the use of pitfall traps. Often deployed on each leg of a bed, pest control operators have also explored the use of these traps in fewer numbers, to attempt to decrease the overall cost of monitoring. While pitfall traps falter as detection tools, because they require 10-14 days to be effective, these excel as monitoring devices. These traps can be improved with bed bug lures, sachets that contain pheromone to attract aggregation seeking bed bugs.

MATERALS AND METHODS

Bed bug detection in the field In a previous laboratory study, we had tested the detection accuracy of TruDetx in detecting bed bug residue (Ko & Choe 2020). However, this study describes the first test of TruDetx in a field environment when compared to bed bug sniffing canine teams and pest control technicians using visual inspection. In an apartment building known to have varying levels of bed bugs, we prescreened apartments for low infestations using pitfall traps. On average, each unit was supplied with 7 pitfall traps, deployed within the single unit apartment room focused in three key areas, the bed, nightstand, and likely resting area. In total, 27 apartment units were selected for the study because they had captured fewer than 20 total bed bugs in the traps that had been deployed for 14 days. For canine inspection, two teams of canine teams were used. Each unit would receive an inspection from each canine unit separately, and the locations where the dog alerted was recorded. For visual inspection, two pest control technicians were used to conduct a fast visual inspection, focusing on the bed, nightstand (if present), and resting area determined by the PCO (such as a reclining chair, wheelchair, couch, etc). Finally, after the canine teams and visual inspectors had conducted their inspection, TruDetx lateral flow strip was used in three locations that had been visually inspected (bed, nightstand, and resting area). This order of inspection was chosen because the canine teams would have the least impact on inspection area. Visual inspection is often the most invasive inspection method, because it requires physical manipulation of the bed and disruption of the resting surface. TruDetx was chosen as the last inspection method to be used because it detects bed bug residue, and would not be affected by the disruption physical inspection could cause; i.e., if TruDetx was used prior to the visual inspection, then it is possible that the use of a swab in cracks and crevices around the bed and resting area would disrupt and move harboring bed bugs, making them easier to detect by visual inspection.

Temprid dust We created an insecticidal dust comprising of beta-cyfluthrin and flupyradifurone amended onto a silica-aerogel dustable powder. We evaluated the efficacy of Temprid dust against a competitive insecticidal dust (Cimexa dust) in residual applications against various strains bed bugs (*Cimex lectularius*). We tested the susceptible Harlan strain, as well as three pyrethroid-resistant strains: Jersey City (highly resistant), Cincinnati (resistant), and South Carolina (slightly resistant). We applied each dust at a rate of 1 g/m2 or 2 g/m2 onto a plywood tile, then exposed various strains of adult bed bugs to the treated surface for a total of 1 minute, then removed the insects from the treated surface and monitored them for mortality in a

clean container for 3 days. Morbidity / mortality of the bed bugs 4 hours after application is shown in Figure 2. Bed bugs were categorized as morbidity or mortality if the non-functional bed bug bodies show any movement after probed. In the study, 5 replicates of 10 insects (5 males and 5 females) were used.

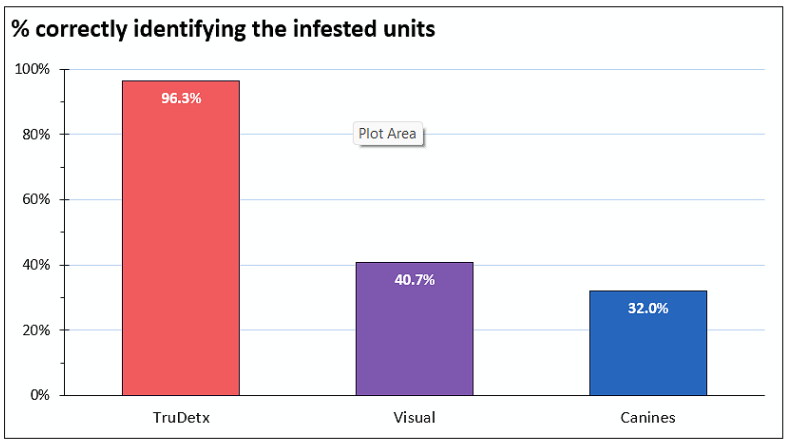

Figure 1. Comparison of detection accuracy of TruDetx lateral flow strips compared to visual and canine inspection of bed bugs.

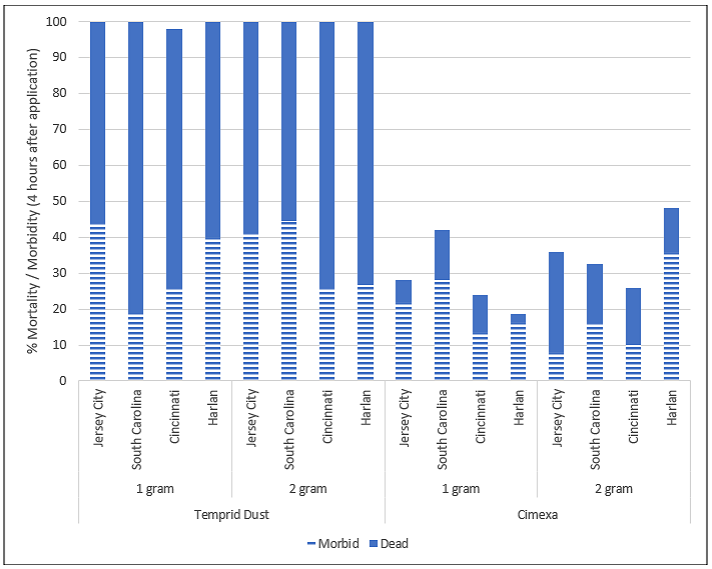

Figure 2. Comparison of Temprid dust efficacy against Cimexa dust at two application rates on plywood tile after 1 minute of exposure to the treated surface.

RESULTS AND DISCUSSION

Bed bug detection in the field comparing canine teams, visual inspection, and TruDetx We find that TruDetx was able to correctly identify 96% of the infested units, visual

inspection correctly identified 40% of the infested units, and canine teams correctly identified 32% of the infested units (Figure 1). One of the primary limitations of TruDetx is the fact that because TruDetx detects bed bug residue, old bed bug residue and new bed bug residue cannot be differentiated by the device. While additional testing (not shown) has determined that bed bug residues generated by 10 fed adult male bed bugs in a 1 cm diameter surface produce residues that would drop below detectable levels after 90 days, pest control operators and more importantly their customers are unwilling to wait for 90 days to learn whether bed bugs are still infesting the location. It is important to note here that all forms of bed bug detection have pros and cons. Visual inspection may be less accurate than lateral flow strips, but the pest control technician conducting the inspection also can interview residents to gain additional information and has access to the pesticides required to get the bed bug population under control. Bed bug sniffing canine teams performed the worst out of all the inspection methods, but canine teams are capable to inspecting a large area extremely quickly. Canines are animals that are motivated by food, treats, attention, and play, and the dynamic that exists between canines and their handlers cannot be overstated. Evidence does exist that canine teams are capable of a high degree of detection accuracy (Cooper et al. 2014), but the high degree of variability in their performance relegates the use of such teams to large-scale detection areas that would not be feasible for labor-intensive visual inspection or lateral flow strips, such as the inspection of call centers, office buildings, etc.

Temprid dust efficacy against various resistant bed bug strains We find that 4 hours after bed bugs of all strains were exposed to the treated plywood surface for 1 minute, Temprid dust alone was able to achieve complete control of the bed bug populations tested (Figure 2). Speed-of-kill is especially important as it related to bed bug management, considering the effect bed bugs have on the psychological safety of people. It is critical that products deployed against bed bugs work swiftly and effectively, as customers do not have the patience to continue getting fed upon after receiving treatment. While both products utilize silica aerogel in their composition, we find that the inclusion of beta-cyfluthrin and flupyradifurone further enhance the efficacy of Temprid dust. For the United States pest management market, Flupyradifurone is a butenolide that exists within a unique IRAC subclass (4D). We believe that flupyradifurone is a welcome addition to pest control operators' toolkit in combating bed bug resistance development in the field.

CONCLUSIONS

Effective bed bug management programs depend on three key phases: bed bug detection, the use of efficacious control products, and monitoring tools. I describe in this paper new data comparing the detection accuracy of TruDetx to bed bug sniffing canine teams and visual inspection by pest control technicians in a field environment. I also describe a new insecticidal dust product, Temprid dust, comprised of beta-cyfluthrin and flupyradifurone amended onto a silica-aerogel dustable particle.

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