T. W. PHILLIPS, M. M. HASAN, M. J. AIKINS, R. MAHROOF

Fumigation and IPM alternatives for arthropod pests of museums

Abstract - Stored-product insects are pests of cultural properties in museums and other collections, and they are represented by species that infest dried animal products and also those infesting dried plant materials. Methyl bromide has been used as an effective control measure to disinfect artifacts, but it is being banned worldwide due to its nature as an ozone-depleting substance. We investigated methyl bromide alternatives for controlling the red-legged ham beetle, Necrobia rufipes, including the available fumigants phosphine, sulfuryl fluoride, carbon dioxide and ozone, and the application of a low oxygen atmosphere using vacuum. The synthetic fumigants phosphine and sulfuryl fluoride gave excellent control of all life stages of the ham beetle in 48-hour treatments conducted at 23°C, but controlled atmosphere treatments were less effective. Among these ozone at close to 150 ppm showed promise. The cigarette beetle, Lasioderma serricorne, thrives on dried plants that contain natural defensive chemicals, such as tobacco, red pepper and numerous other spices and herbs used in cooking, decorations and cultural artifacts. A non-chemical alternative in managing cigarette beetle is the application of mating disruption, in which an unnaturally high level of synthetic sex pheromone is released in an area that results in males failing to locate females with an ensuing population crash. Preliminary field studies in the U.S. suggest that release of the synthetic sex pheromone serricornin can significantly inhibit proper orientation of male cigarette beetles to females and result in reduced reproduction. The work reported suggests that effective alternatives for controlling key museum pests can be developed from chemical and non-chemical approaches.

Key words: controlled atmospheres, mating disruption, pheromones, phosphine, sulfuryl fluoride.

INTRODUCTION

Cultural heritage artifacts composed of biologically-based material are subject to depredation by live organisms such as insects and other arthropods. Stored-product insects, those that consume dried, durable stored plant and animal products are adapted to utilizing such substrates in a variety of contexts (Hagstrum & Subramanyam, 2006). Museum artifacts subject to attack by storage pests are those with dried plant or dried animal products, such as herbs, dried flower arrangements, furs, leather, feathers, taxidermy specimens, woolens and silks, among many others. Insects feeding upon plant
products in museum include some moths (Lepidoptera) in the family Pyralidae and beetles (Coleoptera) in the families Cucujidae, Tenebrionidae and Anobiidae, while pests of animal proteins are predominantly beetles in the Dermestidae and pests of feathers and animal-derived fabrics include the clothes moths in the family Tineidae. The most effective control tactic for stopping and eliminated insect infestations on museum artifacts fumigation with an insecticidal gas, but safety and environmental concerns dictate proper and prudent use of fumigants or may call for alternative to standard fumigation.

The most effective and commonly used fumigant for infested structures and products is methyl bromide (MB), but its use is being phased out and banned worldwide because it contributes to depletion of the atmospheric ozone layer. MB is the ideal fumigant because it can be released from a gas cylinder, directed into a building or chamber containing infested products, kills all life stages of numerous insect species in a matter of hours at warm temperatures, and can be vented from the structure with no residue of the gas or its breakdown products left on the target materials. Research on alternatives to MB has pointed to use of other synthetic chemical fumigants with drawbacks or inadequacies compared to MB, or to the use of controlled or modified atmospheres that are deadly to insects, temperature extremes such as heat or cold that kill insects but may damage buildings and products, or more indirect and less totalitarian approaches such as integrated pest management (IPM) with targeted use of residual insecticides to reduce unacceptable local numbers of pests (Phillips & Throne, 2010).

Our laboratory has been researching alternatives to MB for controlling arthropod pests of dried pork products, including the red-legged ham beetle, Necrobia rufipes and the ham mite, Tyrophagus putrescentiae. The N. rufipes is in the beetle family Cleridae, which are typically insect predators, but this species is a scavenger on drying vertebrate carrion, thus it has adapted to pest status on meat products, and it is a significant pest of museum artifacts with animal products such as aboriginal clothing made with skins, furs and feathers. Here we report on chemical and controlled atmosphere alternatives to MB for controlling N. rufipes. The cigarette beetle, Lasioderma serricorne (Coleoptera: Anobiidae), is a serious pest of stored tobacco and many other stored dried plant materials such as herbs and spices that may be incorporated in cultural heritage artifacts. Here we describe initial work on the non-chemical method of mating disruption using synthetic sex pheromone to suppress populations of this serious pest.

MATERIALS AND METHODS

A laboratory colony of the N. rufipes originated from insects infesting the bone-cleaning facility of the zoology museum at the University of Wisconsin-Madison and was maintained on a mixture of pet food and fish meal at 27°C, 60% R.H. and a photoperiod of 16:8, L:D. Toxicity bioassays were conducted with eggs, larvae, pupae and adults of N. rufipes at various concentrations of MB, sulfuryl fluoride (SF), phosphine gas, hydrogen phosphate (PH₃), Ozone (O₃) and carbon dioxide (CO₂) for 48 h exposure periods at 24°C and 70% R.H. inside the fumigation chambers. Details of the
laboratory fumigation methods, including the quantification of gas concentrations, can be found in Sekhon et al. (2010a, 2010b and 2010c).

Field populations of the *L. serricorne* infesting animal feed mills and pet food plants in the southeastern U.S. were studied for the mating disruption experiment. Mating disruption is a process in which an unnaturally high concentration of a synthetic sex pheromone is released into a target pest habitat resulting in male orientation being disrupted, mating is greatly reduced and the pest population declines and sometimes goes to extinction (Phillips et al., 2000). Mating disruption was recently demonstrated for stored product moths (Phillips, 2006) and has been implemented commercially in Europe and North America. *L. serricorne* populations in all four mills were monitored with pheromone-baited stick traps throughout the course of the study and mating disruption was applied to two of the mills while the other two remained as untreated controls. *L. serricorne* populations were additionally monitored throughout the study by deploying small cups of *L. serricorne* laboratory diet in the mills for mated females to oviposit into. Diet cups were returned to the laboratory monthly where the resulting progeny were counted and level of reproduction assessed. High release pheromone dispensers were deployed every 25 sq m in treated mills.

**RESULTS**

Of the four life stages of *N. rufipes* tested for mortality to MB the most tolerant were the larvae, with a computed LC$_{95}$ of 12.53 g/m$^3$, while eggs were less tolerant at an LC$_{95}$ of 4.93 g/m$^3$ over a 48 hr exposure. For SF gas the adults of *N. rufipes* were easily killed at a concentration of less than 3.0 g/m$^3$, but eggs were much more tolerant and

![Fig.1 - Mean % mortality (SE) of eggs of the red-legged ham beetle exposed to increasing concentrations of sulfuryl fluoride in a laboratory bioassay for 48 h at 24°C.](image)
required doses greater than 19.0 g/m³ to attain 100% mortality of test insects (Fig. 1). Phosphine gas was very effective against all life stages of *N. rufipes* with all life stages being killed at about 0.5 g/m³ in 48 h.

Of the controlled atmosphere treatments ozone treatment over 48 h was not effective against *N. rufipes* when applied at 100 ppm, but treatment above 150 ppm gave nearly complete control of all stages at 48 h (Fig. 2). Carbon dioxide showed low efficacy against *N. rufipes* life stages, with larvae and pupae surviving 70% CO₂ after 144 h (Fig. 3).

Capture of *L. serricorne* in pheromone-baited monitoring traps was significantly reduced in mating-disruption treated mills after mating disruption was initiated compared to the seven weeks prior to treatment with an average reduction of about 35% in beetles trapped. Emergence of progeny from food cups was substantially reduced after treatment in one of the mills, but *L. serricorne* reproduction data were too few to suggest conclusions from this experiment. Research on mating disruption for *L. serricorne* is continuing.

**DISCUSSION AND CONCLUSIONS**

Methyl bromide is clearly the most effective chemical fumigant for controlling all life stages of the *N. rufipes*, but its use is limited and/or prohibited due to the...
treat Protocol and local regulatory restrictions. Of the other chemical fumigants tested, phosphine gas appears to be very effective at low doses for killing *N. rufipes* in 48 h. A serious limitation to the use of phosphine is its ability to corrode copper and other metals such that electronic equipment under fumigation can be damaged (Thomas & Phillips, 2004), which should be considered with the contact of any given fumigation of museum artifacts. Controlled atmosphere treatments studied here did not provide adequate kill or would be logistically impractical for use against *N. rufipes* in museum settings.

Mating disruption for *L. serricorne* shows great promise of effectiveness based on the reduction of trap capture found in the current study. More research is needed to validate effectiveness of mating disruption for *L. serricorne*, and if obtained this method could prove highly effective an approach to managing this important pest in museum settings.

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Thomas W. Phillips & M. Jamie Akins, Dept. of Entomology, 123 Waters Hall, Kansas State University, Manhattan, KS 66506, USA.
E-mail: twpl@k-state.edu
M. M. Hasan, Dept. of Zoology, Rajshahi University, Rajshahi, Bangladesh.
Rizana Mahroof, Dept. of Biological Sciences, South Carolina State University, Orangeburg, SC 29117, USA.