Chemical Alternatives for Managing Key Stored Product Insects

Rizana M. Mahroof

Department of Biological and Physical Sciences, South Carolina State University, Orangeburg, SC 29117

In this short review paper, possible alternatives to manage some key stored product insects pests are discussed. With the phase out of methyl bromide and insects developing resistance to phosphine, fumigants available to manage stored product insects are becoming limited. Potential non-chemical alternatives, those are environmentally benign and do not leave harmful residues on treated products, are most favoured. Two techniques; sex pheromone based mating disruption and ozone gas, are explored as safer insect management tools in this paper.

Introduction

Stored product insects, including the merchant grain beetle, *Oryzaephilus mercator* (Fauvel) (Coleoptera: Silvanidae), cigarette beetle, *Lasioderma serricorne* (F.) (Coleoptera: Anobiidae), and the rice weevil, *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae), cause damage to grain-based products and other durable commodities. Methyl bromide, the most effective fumigant used for the control of these pests, has been now banned because it depletes the ozone layer (USDA 2000, EPA 2006). Phosphine, another fumigant commonly used, faces challenges due to many stored grain insects having developed resistance to the fumigant. Research into potential alternatives has therefore been ongoing. Semiochemical-based insect management to utilize sex-pheromone produced by certain species to implement mating disruption is one viable alternative (Mahroof and Phillips, 2014). Mating disruption is a method in which an unnaturally high level, many milligrams a day, of synthetic pheromone is released into a treated area. Males are unable to locate females that are releasing pheromone at normal levels of nanograms to micrograms per day due to clouds of pheromone.

Gaseous ozone (O₃), a highly oxidising agent and unstable gas has the potential to kill insects, is another potential alternative (Mahroof et al., 2018a, 2018b). These are environmentally safe control techniques that can be used in organic systems. The goal of this paper is to summarise data gathered during several studies done at South Carolina State University, to evaluate mating disruption techniques and ozone toxicity as potential control practices for *L. serricorne*, *O. mercator* and *S. oryzae*.

Synthetic pheromone-based mating disruption to manage *Lasioderma serricorne* in stored products environments

Four food- and feed-processing facilities and a fifth warehouse were selected in South Carolina to conduct mating disruption studies for *L. serricorne*. Details description of the methodology was described in Mahroof and Phillips (2014). Prior to treatment, in each of the facility, *L. serricorne* populations were monitored throughout the year, using traps lured with synthetically produced *L. serricorne* sex pheromone. Oviposition cups were used as an additional tool to monitor beetle populations that are independent of response to the pheromone. Mating disruption experiments were carried out for two subsequent years in three of the five facilities selected. Remaining two facilities served as control studies, not being treated with high dose of pheromone. Pheromone release devices were deployed in mid-summer at all treated sites at a spacing density of 1 device per 250 ft². The experimental evaluation was done by comparing beetle captures for several weeks prior to the beginning of the mating disruption and then continue monitoring beetle activity in the same way after beginning of mating disruption using both traps and ovipositional cups.

In all treated facilities, immediate monitoring trap shutdown indicated signs of failure for male beetles to locate female *L. serricorne* (Table 1). Reduction in number of male beetles caught in traps in the subsequent months of mating disruption treatment proves that mating might have been disrupted or delayed in treated facilities both years (Figure 1). In this study, a complete trap shutdown was not observed although number of beetles caught in traps after treatment had significantly reduced.

### Table 1. Mean (±SE) of cigarette beetles captured two and seven weeks before and after dispensing mating disruption dispensers in a facility

<table>
<thead>
<tr>
<th>Time (weeks)</th>
<th>Mean ± SE of <em>L. serricorne</em> before treatment (n=25)</th>
<th>Mean ± SE of <em>L. serricorne</em> after treatment (n=25)</th>
<th>(t)-value (df)</th>
<th>(P)-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>27.04 ± 9.03</td>
<td>3.28 ± 3.08</td>
<td>4.47 (24)</td>
<td>0.0002</td>
</tr>
<tr>
<td>8</td>
<td>8.75 ± 3.53</td>
<td>2.60 ± 1.09</td>
<td>3.43 (24)</td>
<td>0.0023</td>
</tr>
</tbody>
</table>

Results also showed that reduction in adult beetles emerged from oviposition cups that were collected soon after mating disruption was launched, to another extent proved that gravid females are reduced or absent in the treated facilities.

If males were not able to locate pheromone source placed in traps, it is assumed that it would be unlikely for them to find a calling female (Mahroof and Phillips, 2014). There may be several mechanisms that may have prevented male beetles attracted to the monitoring lures and landing in a trap. Researchers have shown that pheromone originating from several sources including a high concentration from the mating disruption device, from calling females and monitoring lures forms clouds of pheromone in the air. When a male exposed to clouds of rapidly changing concentration of pheromones, then the male antennal sensory structures may fatigue and no longer respond to the pheromone (Leal, 2003). Thus, mating get delayed or disrupted leading to fewer progenies produced in the subsequent generation.

#### Fig. 1

Mean ± SE number of cigarette beetles captured in sticky traps in treated mills eight weeks before and after mating disruption treatment. Data were analyzed by two-way ANOVA using the GLM procedure of SAS. Tukey Groupings were used \(\alpha = 0.05\). Bars followed by different letters are significantly different from each other.

Mills

Table 1
Toxicity of ozone gas to external and internal feeders of grain

A bench-top, custom made ozone generating equipment was obtained and used for the study (Ozone Solutions Inc. Hull, IA). Briefly, the equipment takes up oxygen from air, which is broken apart and recombined into ozone. The required concentration is then set and released into a chamber into which test specimens are placed. Adults of *O. mercator* and *L. serricorne* were exposed to ozone concentrations of 100–400 ppm with an increment of 100 ppm for one hour (h) with their specific diets or without diet. Adults of *S. oryzae* were exposed to 200 ppm for 12–48 h. The adults were placed at the 5, 15, or 25 cm depth in a PVC pipe containing wheat. For each experiment, set-ups similar to those exposed to ozone served as the control. All adults, both exposed and unexposed, were observed for survival immediately after ozone exposure, and again at 1 and 2 days after treatment (DAT).

In *O. mercator*, for all concentrations tested, there was no significant difference between days or between a treatment and its respective control when food is present or absent (Figure 2). Survival of adults treated without food significantly reduced 1-2 DAT.

Survival in *L. serricorne* adults exposed to 100–400 ppm ozone for 1 h is presented in Figure 3. Survival generally decreased with increase in concentration. At 400 ppm tested, approximately 79% adults survived when treated without food, and 82% survived when treated with food by 2 DAT.

Survival of *S. oryzae* is presented in Figure 4. Except for 12 h exposure at 25 cm depth, for all other exposure times and depths, survival of treated adults was significantly lower than their corresponding controls. As exposure time increased, survival at each depth decreased. Survival at 5 cm depth was 0% for all exposure times, while survival at 15 cm was significantly higher for 12 h exposure than survival at all other exposure times which were similar. At 25 cm depth, survival for 12–36 h exposure times were similar and significantly higher than survival for 48 h.

In this study, we report the effect of ozone on *O. mercator*, *L. serricorne*, and *S. oryzae*. Even at low concentrations, delayed toxicity effect was reported in all species: fewer adults exposed to ozone survived in subsequent days compared to the survival in earlier days. This was more pronounced when insects were treated without food (Mahroof et al., 2018a and 2018b; Amoah and Mahroof, 2018). Our findings agree with Subramanyam et al. (2017) who suggested that toxicity caused by ozone is usually delayed due to its mode of action. Significantly lower survival was recorded at 5 DAT compared to 1 DAT when adult *Rhizopertha dominica* (Fabricius) (Coleoptera: Bostrichidae) were exposed to ozone concentration of 200 or 400 ppm.

Ozone is absorbed by grain and penetrates through food by diffusion (Raila et al., 2006). This was noticed in our study when we compared survival in insects treated in the presence of food and those treated in the absence of food. Hence, there is the need to increase concentration and/or exposure time to achieve 0% survival in *O. mercator* and *L. serricorne* especially in the presence of food and 0% survival in *S. oryzae* at the deeper depths of the wheat in the PVC pipes.

Overall, our study has shown that the use of synthetic pheromones for mating disruption has proven to be effective for *L. serricorne* in stored products environments. Results showed significant reduction in the number of male beetles caught in traps. This result is an indication of pheromone effects and signify successful mating disruption. It is worth to note that the reduction in trap catches among treatments is not always proportional to the reduction of product damage or changes in pest population density. However, this study proved that a greater potential does exist to commercialize the use of mating disruption techniques to effectively manage *L. serricorne* in stored products environments. Furthermore, experiments with ozone showed that ozone has the potential to control *O. mercator*, *L. serricorne*, and *S. oryzae*. Future studies may show that higher concentrations of ozone, longer exposure times, or a combination of these increase the effectiveness of ozone. Mating disruption or use of ozone to control important stored product insect pests seems a promising alternative to conventional control methods.
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Notes and References

*Corresponding author email: rmahroof@scsu.edu


