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The Australian standard alone does not ensure that efficacious phosphine fumigations can be administered; however it is the first step in ensuring a grower has the correct system in which to undertake an efficacious and safe fumigation.

Stakeholders across the grains value chain are asking for and disseminating best practise information through their networks and the many grower workshops and field days conducted through the national extension project and industry forums. Development of the various information packages covering best management practises for on-farm storage and fumigation provides a mechanism for growers and industry to support the training and knowledge development they have undertaken. The phosphine booklet "Fumigating with phosphine, other fumigants and controlled atmospheres" was a comprehensive and farmer friendly publication covering sealed storage management, silo testing and best practise fumigation. The Australian standard provided growers with the tools to select sealed storage, the extension program and information packages built on and supported best practise fumigation and grain storage.

At workshops and field days growers are taught the theory behind a successful fumigation and with practical demonstrations shown the features of a gas-tight sealed silo, how to maintain and replace seals and how to perform a standard pressure test to test whether they are sealed. A website www.storedgrain.com was developed to further provide a source for growers and industry to look for and download information.

Using mediums such as websites and the media allowed specific and timely information to be brought to the attention of growers and industry and to promote key messages when necessary. An example of this was a major media campaign using rural media and industry networks promoting and discussing the Australian standard for sealed silos, which was a great success and very quickly converted to growers actively asking whether silos being considered and or purchased met the standard.

Newspaper and newsletter articles and radio interviews are regularly released to promote best practise fumigation and grain storage practises when the information is timely and can be used to assist farmers in their storage management.

The accredited phosphine training module has had a minor uptake to date, largely due to growers still not being required to undertake training specific for the use of phosphine in all states except New South Wales. Currently New South Wales farmers are required to undertake phosphine training as a Work Cover (Occupational Health and Safety regulator) requirement. State regulators of chemical use are currently considering mandatory training for phosphine use, particularly in Victoria. The introduction of training is being considered as part of a response by regulators to the potential label changes for phosphine being proposed to the APVMA (Australian pesticides and veterinary medicines authority).

Overall the extension project has had a positive impact on improving the efficacy of phosphine fumigation in on farm fumigation. Growers are actively asking for Australian Standard Compliant sealed silos. Growers, industry and agribusiness are asking for and disseminating best practise information through their networks, and there has been a continuing demand for workshops and field days and addresses at industry forums.

Temporal and Spatial Patterns in Aerosol Insecticide Droplet Distribution: Modifying Application Strategies to Improve Coverage and Efficacy

James F. Campbell*, Frank H. Arthur, Daniel Brabec, Deanna Scheff

USDA ARS, Center for Grain and Animal Health Research, 1515 College Ave, Manhattan KS, 66502, USA, email:

*Corresponding author: james.campbell@ars.usda.gov.

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Abstract

With the phase-out of methyl bromide, treatment of food facilities with aerosol insecticides as part of management programs has increased. The physical layout of the structure, the distribution of equipment and other items within the space, and the application method and location may all cause spatial variation in how the insecticide is deposited, which can result in areas with insufficient or excessive amounts of insecticide applied. The impact of aerosol insecticide application position and dispersal method/formulation on the distribution of droplets was evaluated using a series of applications within the same flour mill room. The spatial pattern of droplet distribution and the effect of treatment on bioassay insects (*Tribolium confusum* Jacquelin DuVal) was evaluated. There was variation in aerosol concentration and droplet size distributions within room and application position had an impact on the spatial pattern of aerosol droplets. The further away and more obstructed by structural features a location was the lower the aerosol concentration, but concentration was also lower to the side and behind the release point. Evaluation of the temporal pattern in droplet deposition shows that most larger droplets settle out of the air relatively quickly, supporting that idea that shorter shutdown times are possible. Efficacy was correlated with droplet concentration. The overall conclusion is that there can be considerable variation in distribution of aerosol insecticides and as a result considerable potential for improvement in the effectiveness of these applications.

Keywords: insecticide, aerosol, flour mill, *Tribolium confusum*, efficacy, spatial distribution.

1. Introduction

Some insecticides can be applied as aerosol treatments which involves atomizing the liquid insecticide and carrier and dispensing as small particles ranging in size size from 5 -50 μm . Use of aerosol applications using reduced risk insecticides such as pyrethrins, pyrethroids, and insect growth regulators has increased with decreased use of structural fumigations in food facilities. Application of insecticides as aerosols offers the advantage over other spray methods in that more complete coverage of surfaces within a food facility can be obtained. However, information on the coverage that is actually achieved and the impact of variation in aerosol deposition on efficacy remains limited. Aerosol droplets have limited ability to penetrate into machinery or commodities so they don't function like a fumigant and they also have limited ability to disperse under obstructions. This can generate areas with inadequate coverage with insecticide and can result in reduced efficacy (Campbell et al. 2014; Kharel et al. 2014; Arthur et al. 2018). Evaluations of spatial patterns in aerosol distribution can be done using bioassay insects (e.g., Campbell et al. 2014), but using particle size measuring equipment can improve our understanding of what is happening during aerosol treatments (e.g., Arthur et al., 2018). Understanding the spatial pattern in both aerosol droplet size and concentration is important given that droplet size impacts both dispersal but also efficacy, given that smaller droplet sizes tend not to be efficacious against insects (Arthur et al. 2014).

Previous research has shown that there is spatial variation in efficacy against stored-product insects within a facility, presumably due to uneven aerosol dispersal and deposition patterns (Arthur and Campbell 2008, Campbell et al. 2014, Arthur et al. 2018). When aerosol treatment with a combination of pyrethrin and insect growth regulator was applied from one location within a flour mill there were areas with high efficacy, typically in open areas in the center of the room, and areas with low efficacy, typically in corners, behind application point, obstructed areas, and locations farthest from application point and which had the most physical obstructions between point of release and where measurements were taken (Arthur and Campbell 2008; Campbell et al. 2014). As a result, a critical question is how can coverage of these treatments be improved so that get more even coverage and efficacy within a space. The aerosol formulation and delivery method are likely to be important variables, since velocity at release and droplet size distribution produced will impact the distribution and deposition of aerosols. Also, where the aerosol is applied within a space is also likely to impact coverage, given that barriers and distances that need to be traveled by droplets will vary with release point. In these tests, we evaluated the impact of application point and formulation type on coverage of aerosol treatments. Specifically, we used a combination of droplet size and concentration measurement and bioassay insects to evaluated spatial pattern in aerosol

applications when aerosols were applied from one of three locations or if aerosol application was split among all three locations.

2. Materials and Methods

Aerosol applications were conducted at the pilot scale flour mill at Kansas State University, on the third floor which is roughly L shaped, 13.5 x 21.0 m in main area and 7.5 x 6.5 m in the smaller offshoot of the main area (volume of approximately 1,504 m³). Aerosol applications were applied by a commercial applicator using the label rates of (1) cylinderized formulation of a combination of pyrethrin and the IGR pyriproxyfen (TurboCide Py-75 with IGR, Chem-Tech Ltd., Des Moines, IA, USA) and (2) combination of pyrethrin (BP-100, BASF Corp., Research Triangle Park, NC) and the IGR methoprene (Diacon® IGR, Central Life Sciences, Schaumburg, IL, USA) applied using a portable handheld mechanical fogger hand applicator.

Each aerosol was applied from one of three locations within the mill, or the application was split equally among the three locations (Fig. 1). Treatments were replicated three times. Aerosol distribution was measured using bioassay dishes containing confused flour beetles, *Tribolium confusum*, and Aerodynamic Particle Sizer (APS) spectrometer 3321 units (TSI Inc., Shoreview, MN, USA) placed at different locations within the mill (Fig. 1). After one hour of treatment, the room was vented and the bioassay insects collected and evaluated on whether they showed signs of being effected by the insecticide and then held for 14 days and assessed again and number alive, dead, or knocked down was recorded.

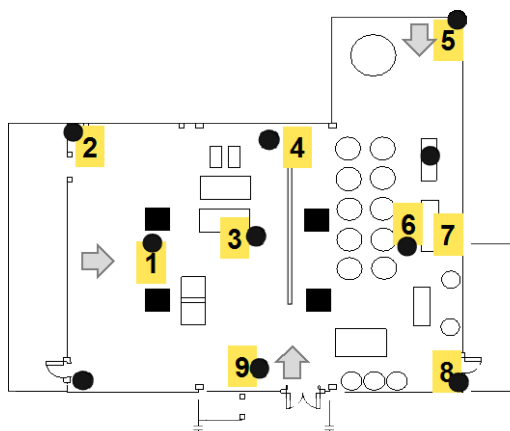


Fig. 1 Floor plan of the flour mill where the aerosol tests were conducted, with aerosol application release points and directions indicated with gray arrows, positions of the aerosol particle size analyzers indicated by numbers in yellow boxes, and positions of the bioassay dishes indicated by the black circles.

3. Results

Number of aerosol droplets, droplet size distribution, total concentration in air (mg/m³), and estimated deposition on surfaces (ug/m²) were calculated for each location/treatment combination. Example of the temporal and spatial pattern in total concentration and mean particle size is shown in Fig. 2. Total droplet concentration decreased with distance from application point and in more obstructed locations, and at all locations within the mill the total concentration had dropped to low levels after less than 20 min and remained unchanged until the end of the treatment. There was considerable variation in the estimated deposition on surfaces among locations, with greatest estimates near point of application and dropping as move further away or if more obstructed. Aerosol application location did impact which locations had higher concentrations of aerosol, but all application locations and formulations resulted in patterns of high and low deposition. Splitting

the application among three locations increased the number of locations with higher deposition but in all treatments had locations with low deposition.

There were significant differences in bioassay insect knockdown immediately after treatment and mortality after 14 days among application location/treatment combinations. Application location did result in differences in the pattern of efficacy but regardless of whether released from one of the three locations, or split among three locations, there continued to be zones where beetles survived treatments (Fig. 3).

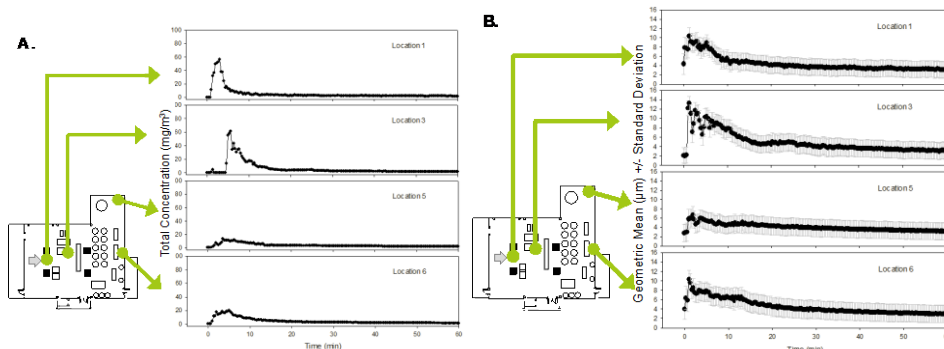


Fig. 2 Example of how total concentration (A.) and geometric mean droplet size (B.) varied among locations and changed over time after start of treatment, using results of one trial using the cylinderized formulation of pyrethrin and pyriproxyfen released at one location (only four the APS units shown for clarity).

4. Discussion

Results of this study show that there is spatial variation in the distribution of droplets that is impacted by release location and the insecticide formulation/application method. There was also a correlation between droplet deposition and efficacy using bioassay insects, suggesting that it is the droplet characteristics that are causing variation in efficacy. As expected, distance and physical barriers contributed to reduced droplet concentrations and droplet sizes, and were associated with lower efficacy. An exception to this pattern is that locations behind where the applicator stood often had reduced aerosol deposition and bioassay efficacy, suggesting that the release velocity of droplets resulted in limited drift of droplets back into the area of release. Unfortunately, none of the different application locations evaluated, including releasing aerosol split among all three locations, resulted in all locations having high efficacy. Further evaluation of other patterns of aerosol release and use of fans to facilitate movement of droplets is needed.

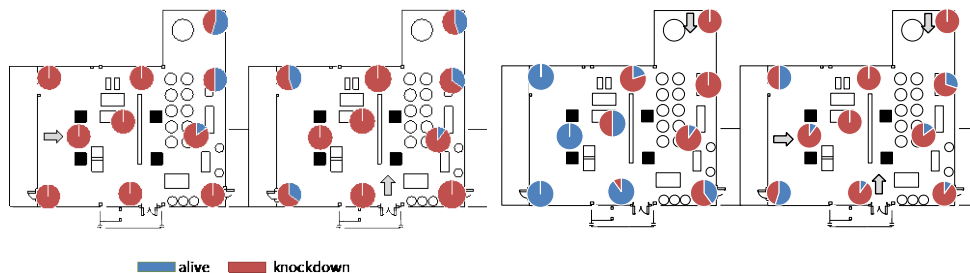


Fig. 3 Example of effect of application location on bioassay insects (*T. confusum*) immediately after exposure to aerosol at different locations, using results of one trial with cylinderized formulation of pyrethrin and pyriproxyfen. Each floor plan has an arrow to indicate the aerosol application location and direction and the pie charts represent the percentage of beetles alive or knocked down immediately after the treatment.

Our results bioassay results are meant to be used as indicators of aerosol concentration, not necessarily as an indicator of overall effectiveness of a treatment against a resident pest population. First, we did not include the impact of the insect growth regulator in the aerosol formulation. Initial evaluations indicate that because much smaller amounts are needed for efficacy that more consistent high efficacy is found using larvae exposed to surfaces at different spatial locations. Second, the spatial pattern of insects in the facility and how much of the population is hidden in areas aerosol cannot reach is not known. In most situations we would predict that large portions of the population will not be directly exposed to the droplets during an application. Contact with treated surfaces and materials after the aerosol application is likely to be more important in terms of the overall impact of a treatment on the pest population.

Aerosol insecticide applications have tended to be a black box and little information was available on the impact of the treatments. Research presented here is part of a broader research effort to understand these treatments better, to make them more effective, and to be better able to predict the best strategies for using reduced risk aerosol insecticides.

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Technical improvement of the Detia Degesch Phosphine Tolerance Test Kit

Goetze Marie-Carolin¹, Steuerwald Renate¹, Agrafioti Paraskevi², Sakka Maria K.², Jakob Gerhard¹, Athanassiou Christos G.²

¹ Detia Freyberg GmbH, Dr.-Werner-Freyberg-Str. 11, 69514 Laudenbach, Germany

² University of Thessaly, Department of Agriculture, Crop Production and Rural Environment, Laboratory of Entomology and Agricultural Zoology, Phytokou str., N. Ionia, 384 46, Magnesia, Greece

Corresponding author: carolin_goetze@detia-degesch.de

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Abstract

Phosphine is the most important commonly used fumigant for the control of stored product insects in warehouses and processing facilities globally. However, the improper and extensive use has led to reduced susceptibility to phosphine for several insect species and strains in many parts of the world. To evaluate and quantify this phenomenon, Detia Degesch developed the Detia Degesch Phosphine Tolerance Test Kit (DDPTTK) more than 10 years ago. The use of DDPTTK is based on the exposure of the insects on a high concentration of phosphine (e.g. 3000 ppm) for short exposure periods (e.g. 8-15 min). This kit can be used on site by the fumigation and food industry, and can provide immediate results on the tolerance status of the insect strains that are to be treated. So far, the instructions of DDPTTK refer only to a six insect species. In this work, data for