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Food source effect and residual efficacy of chlorfenapyr as a surface treatment on sealed and unsealed concrete

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ABSTRACT

Adults of *Tribolium castaneum* (Herbst), the red flour beetle, were exposed at 1 day, and 2, 4, and 6 weeks post-treatment on sealed and unsealed concrete arenas treated with chlorfenapyr at rates of 2.8, 6.9, 13.8, 20.6, 27.5 mg active ingredient/m^2. Beetles were held either with or without flour, and assessments were done of the percentage of mobile beetles after 24 h and after 1 wk, and the percentage of beetles knocked down and dead after 1-wk. Although the percentage of adults that were still mobile after 24-hr of exposure increased on sealed and unsealed concrete with increasing post-treatment interval, there were less mobile adults on the arenas without flour compared to those with flour in week 0, but the opposite was true at weeks 2, 4 and 6. At the one week assessments, there were usually more beetles remaining mobile and more beetles knocked down on arenas with flour compared to those without flour, and more dead beetles on arenas without flour compared to those with flour. Sealing did not have a clear beneficial effect. The presence of the flour food source generally decreased efficacy of the insecticide, regardless of concentration.

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1. Introduction

Residual contact insecticides can be used as part of insect management programs for mills, processing plants, and warehouses containing stored food products (Arthur, 2012). They can be used as crack and crevice sprays or spot treatments, and also as general surface treatments to a flooring surface. In the United States (US), the insecticide label will specify directions as to how the insecticide is to be applied depending on the use. Currently the pyrethroids deltamethrin and cyfluthrin, and the insect growth regulators hydroprene, methoprene, and pyriproxyfen, are labeled for use as a general surface spray in the US.

There are many factors that affect residual efficacy of general surface sprays, including the target insect pest species and life stage, the specific insecticide and formulation, the temperature at the time insects are exposed and also during a post-treatment time period, and the specific surface substrate (Collins et al., 2000; Toews et al., 2003; Wijayaratne et al., 2012). Studies with the emulsifiable concentrate and wettable powder formulations of cyfluthrin (Tempo® EC and WP, respectively) showed that the application of a water-proofing sealant prior to insecticide application improved residual efficacy on a concrete surface (Arthur, 1994). However, a recent study with the newer cyfluthrin formulation available now (beta-cyfluthrin, Tempo® SC Ultra) did not show an appreciable benefit to using a sealant (Arthur et al., 2015).

The insecticidal pyrolle chlorpenapyr (Phantom®) has been evaluated as a potential protectant of bulk stored grain (Athanassiou et al., 2009, 2014; Kavallieratos et al., 2012) and also as a general surface treatment for control of stored product insects (Arthur, 2008, 2009; Arthur and Fontenot, 2012a). It is effective as a surface treatment at lower rates than specified on the label for use as an outside perimeter spray for spot treatment against *Tribolium castaneum* (Herbst), the red flour beetle, a common insect pest of storage facilities in the US (Arthur, 2013). There are no published data in the scientific literature regarding the use of a sealant to improve residual control from chlorfenapyr, or how the presence of a food source contamination affects degradation. Therefore, the objectives of this study were to determine if: 1) sealing concrete improved residual efficacy of chlorfenapyr, and 2) the presence of a flour food source affected degradation and efficacy.

2. Materials and methods

This test was conducted in a laboratory at the USDA-Center for Grain and Animal Health Research (CGAHR) in Manhattan, KS. The

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insecticide used was an Emulsifiable formulation of chlorfenapyr (Phantom®), 21.45% active ingredient [AI], 240 mg/ml, BASF Corporation, Research Triangle Park, NC, USA. Label directions specify mixing 89 ml of product in 3784 ml of water to create a 0.5% concentration, and this dilution is to be used at a maximum of 35.4 ml per 1858 cm^2 as an outside perimeter spray.

Individual experimental units were created by using a driveway patching material (Rockite®, Hartline Products, Cleveland, OH, USA) mixed with water to create a liquid slurry. This liquid was then was then poured into the bottom portion of a plastic disposable Petri dish with an approximate area of 62 cm^2 to create individual exposure arenas. Each arena was filled to a depth of about 1.25 cm with the concrete-water mixture to create a flat smooth surface. A total of 384 arenas were created for the study. After drying, half of the arenas were sealed with a common water sealant contained in an aerosol can, purchased at a local hardware store. The aerosol can was equipped with a thin exterior nozzle extension, and the sealant was applied to each arena by hand-holding the can so that the nozzle was about 3 cm from the arena surface, and spraying the sealant in a circular pattern to coat the entire surface. The resulting sealed surface was smooth and could be visually distinguished from the unsealed concrete.

The volume rate of chlorfenapyr to be applied to the 62 cm^2 area of the concrete arena, was 1.2 ml, which was equivalent to the volume rate specified on the insecticide label. This gave a concentration of 0.11 mg AI/cm^2 or 1100 mg/m^2 (100% of the label rate). For this test insecticide solutions were prepared in different volumetric flasks to produce concentrations that were 0 (untreated control with distilled water), 1, 2.5, 5, 7.5, and 10% of the labeled rate (6 concentrations). Instead of applying the insecticide at the label volume of 1.2 ml per the 62 cm^2 area of the arena, 0.3 ml was used, which further diluted each concentration by 75% of the AI in the dilutions described above. Thus, the final deposition corresponding to those dilutions was 2.8, 6.9, 13.8, 20.6, 27.5 mg AI/m^2. There were four individual replicates, each treated separately by preparing different solutions for each of the four replicates, in a Completely Randomized Design. For each concentration and each replicate, two sets of four sub-replicates of sealed and four sub-replicates of unsealed arenas were treated each time. Replicates one and two were treated on one day and replicates three and four were treated the next day. The day following treatment for both sets of replicates, 300 mg of flour was added to each individual arena in one set of the four sub-replicate sets of sealed and unsealed arenas for each replicate and concentration. The other arenas in the second set of sub-replicates did not contain flour. Ten 1–2-week-old adults of *T. castaneum*, obtained from a pesticide-susceptible strain cultured on a mixture of 95% whole-wheat flour and brewer's yeast, were placed in each arena for the two replicate sets. The two replicate sets were done on successive days because of the time required for the exposure studies, as explained below.

After the beetles were placed on each arena for each of the two sub-replicate sets for each replicate and concentration, all arenas were transferred to an incubator set at 27 °C and 60% relative humidity (r.h.). After 24 h, the arenas were removed, and adults classified as active and running (hereafter termed mobile), knocked down (on their backs and affected by the insecticide), or dead (mortality, unable to respond when prodded with a probe). The arenas were returned to the incubator, and one week after the adults were first placed on the arenas, all arenas were removed from the incubator, and beetles classified as mobile, knocked down, or dead. The beetles were discarded, a brush was used to clean all flour the sealed and unsealed arenas that contained flour, and all arenas were stacked on a laboratory counter. The temperature and r.h. on the counter was monitored with a Hobo recording computer (Onset Computers, Bourne, MA, USA). Throughout the study, the temperature inside the laboratory room was about 25 °C and 40% r.h. After one, two, four, and six weeks, the entire exposure process was repeated and flour cleaned from the arenas before the next assessment, as described above.

The main factors evaluated were insecticide concentration, exposure time (24 h and 1 week of exposure immediately after surface treatment), residual efficacy (1, 2, 4 and 6 weeks post-treatment), sealed versus unsealed concrete, and arenas with no flour versus those that had flour. The test was analyzed as a repeated measure because exposure assessments at 24 h and 1 week and the residual assessments were done on the same experimental units. Analysis was done using the General Linear Models (GLM) Procedure in the Statistical Analysis System (SAS Version 9.1, SAS Institute, Cary, NC, USA). Means were separated ($P < 0.05$) using the Waller–Duncan *k*-ratio *t*-test option under GLM.

3. Results

Main effects concentration, flour, and sealant were all significant for percentage of beetles that remained mobile after the 24-hr

Table 1
Main effects for variables concentration (conc.) flour (with or without), sealant (with or without) for % of adult *T. castaneum* mobile after 24 h, % mobile after 1 wk, % knocked down (KD) after 1 wk, and % mortality after 1 wk of exposure on concrete arenas treated with 2.8, 6.9, 13.8, 20.6, and 27.5 mg AI chlorfenapyr/m^2. Statistical parameters are mean square (MS), *F* and *P*-values for the main effects. DF is degrees of freedom, MS is mean square.

Effect	DF	MS	*F*	*P*
% Mobile-24 h				
Conc.[a]	5	6497.9	9.2	<0.01
Flour[a]	1	3659.6	5.2	0.03
Sealant[a]	1	5445.7	12.0	<0.01
Conc. × flour[a]	5	2929.0	4.1	<0.01
Conc. × sealant[a]	5	396.3	0.6	0.72
Flour × sealant[a]	1	405.0	0.6	0.46
Rep × sub-rep × conc. × flour × sealant	24	705.8		
Week	3	6703.9	25.1	<0.01
Error	1403	266.8		
% Mobile-1 wk				
Conc.[a]	5	39,855.4	32.3	<0.01
Flour[a]	1	63,415.5	51.5	<0.01
Sealant[a]	1	12,055.6	9.8	<0.01
Conc. × flour[a]	5	18,507.5	15.0	<0.01
Conc. × sealant[a]	5	396.3	2.3	0.08
Flour × sealant[a]	1	405.0	0.4	0.51
Rep × sub-rep × conc. × flour × sealant	24	1231.9		
Week	3	6703.9	162.1	<0.01
Error	1394	266.8		
% KD-1 wk				
Conc.[a]	5	1422.9	4.7	<0.01
Flour[a]	1	81,219.8	268.5	<0.01
Sealant[a]	1	9063.6	30.0	<0.01
Conc. × flour[a]	5	406.2	1.3	0.28
Conc. × sealant[a]	5	193.4	0.6	0.67
Flour × sealant[a]	1	8804.1	29.1	<0.01
Rep × sub-rep × conc. × flour × sealant	24	302.5		
Week	3	7388.3	39.7	<0.01
Error	1394	186.3		
% mortality-1 wk				
Conc.[a]	5	54,733.2	44.2	<0.01
Flour[a]	1	288,170.6	232.7	<0.01
Sealant[a]	1	213.0	0.2	0.68
Conc. × flour[a]	5	19,202.3	15.5	<0.01
Conc. × sealant[a]	5	2318.4	1.9	0.13
Flour × sealant[a]	1	13,797.4	11.1	<0.01
Rep × sub-rep × conc. × flour × sealant	24	1238.6		
Week	3	39,476.0	142.5	<0.01
Error	1394	277.0		

[a] Denominator MS value is the rep × sub-rep × conc. × flour × sealant error term used for the repeated measure analysis (PROC GLM, SAS Institute).