Human behaviour and application of residual insecticides to control storage and food industry pests

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Abstract

We measured the individual variation of the area-estimate of simple geometrical patterns (circle, rectangle) in ten people. We found that they tended to underestimate (max. 5 x) the correct area of the tested geometrical patterns. Consequently, we explored how the insecticides Ficam 80WP, K-Othrine 25, and Actellic EC50 are robust or sensitive to the measured extent of over-dosage (2x) or under-dosage (5x). We also tested the effects of incorrect dosages of insecticides applied to porous filter paper nonporous glass and bioassayed with adult *Sitophilus oryzae* and *Tribolium castaneum*. We found that the tested insecticides were surprisingly robust to under-dosage on the glass surface but sensitive to under-dosage on the porous paper surface.

Keywords: Pesticides, Insecticides, Residual treatment, Dosage, Human behaviour

1. Introduction

The contemporary management of storage pests still relies primarily on chemical and physical control (Zettler and Arthur, 2000; Huang et al., 2004). Residual sprays are routinely employed as surface treatments (Zettler and Arthur, 2000, Hubert et al., 2007) to control dispersal of stored product pests from cracks and crevices (Arthur et al., 2006; Kucerova et al., 2003). Methods and strategies of pesticide application to control stored food product and public health pests have been reviewed by Zettler and Arthur (2000). Generally, pesticide application equipment should be designed to deliver the correct amount of active ingredient to the proper place in the most efficient and economical way. The prerequisite of good efficacy and safe use of any residual insecticide is also the ability of the human-applicator to deliver a proper (label) dose of active ingredient to a target surface. In contrast to mechanized and automated insecticide application equipment for crop fields and orchards, the application of insecticides to food industry premises relies mainly on human labour and behaviour. Notably, the proper dosage of insecticide largely depends on the human applicator and the individual's perception and estimate of the area to be treated.

The objectives of this research were to: 1) to estimate the extent of variation in individual perception and estimate of the simulated area (two simple geometrical patterns, a circle and rectangle) to be treated, and 2) explore how are various insecticides (Ficam 80WP, K-Othrine 25, Actellic EC50) are sensitive to over-dosage or under-dosing stemming from an incorrect estimate of the treated area.

2. Materials and methods

In the initial stage of the experiment we measured the extent of individual variation of the human area-estimate. We asked ten individuals, all of whom reached at least middle school education level, to estimate an area two simple geometrical patterns (a circle and rectangle) measuring 24.5 cm^2 printed on paper, without using any measurement tools. We tried to simulate the field situations when pest control persons frequently estimate the area to be treated by a residual insecticide without any measuring equipment. The aim of our experiment was to determine the maximal and minimal estimate-departures (i.e., extreme values) from the correct value of 24.5 cm^2. The overestimated and underestimated values were then used for the consequent experiments modelling biological effects of over-dosing or under-dosing of three insecticides.

As a reference, the following labelled doses were used: Actellic 25 EC-8% (1.0 g pirimiphos methyl m^{-2}), K-Othrine 1% (0.0125 g deltamethrin m^{-2}), Ficam W 0.3% (0.12 g bendiocarb m^{-2}). Concurrently, we tested the effects of incorrect dosages of insecticides on a porous and nonporous surface to control *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) and *Tribolium castaneum* (Herbst) (Coleoptera:

Tenebrionidae): For maximal over-dosage (2x) or under-dosage (5x) we used data from Table 1. Plain glass Petri dishes (diameter, 150 mm) were used to simulate a non-porous surface. To simulate an extremely porous surface we used five layers of Whatman No. 4 filter paper (medium retention and flow rate) fixed to the bottom of Petri dishes. The diluted insecticides were evenly applied on the treated surfaces and left to dry for 24 h at 20°C. Diluted insecticide formulations were applied (10 mL) by a micro-syringe (Socorex Acura 825 autoclavable 100-1000 µL) evenly over a treated surface. In experiments, we used 20 insects in each paper/Petri dish in 10 repetitions for each treatment. A short term exposure of 10 min (Arthur, 1998; Stejskal et al., 2009) was used, after which beetles were added to new Petri dishes. We assessed mortality 102 h after exposure.

3. Results and discussion

We explored the influence of over dosage and underdosage on short exposure efficacy of Ficam 80WP, K-Othrine 25, Actellic EC50 to two stored-product beetles. We tested the potential influence of human applicator behaviour on the incorrect dosage of insecticides. The extent of incorrect dosage was derived from human incorrect estimate of the surface area. Table 1 shows the surface-area estimate of two geometrical patterns (circle and rectangle) printed on the paper, performed by ten experimental persons. We found that the experimental persons tended to underestimate (max. cca 5x) rather than to overestimate (2x) the correct area of the tested geometrical patterns. This small-scale (cm^2) estimate should be verified at larger scale in field conditions.

Table 1 The surface-area estimate of two geometrical patterns (circle and rectangle of 25.4 cm^2) printed on the paper performed by 10 experimental persons, maximum (Max.) and minimum (Min.) values.

Geometrical pattern	**Circle**		**Rectangle**	
	Max. value	**Min. value**	**Max. value**	**Min value**
Estimated area	50 cm^2	5 cm^2	50 cm^2	12 cm^2
Ratio to the correct value	2,1x higher	4,9x lower	2,1x higher	2,1x lower

Tables 2 and 3 show differential robustness of the tested insecticides to the simulated extent of over-dosage (2x) or under-dosage (5x) on porous and non-porous surfaces in *T. castaneum* (Table 2) and *Sitophilus oryzae* (Table 3). We found that the tested insecticides were surprisingly robust to under-dosage on the glass surface while they were sensitive to under-dosage on the porous paper surface. We also found site-specific differences: *Sitophilus oryzae* was more sensitive to the under-dosed insecticides compared to *T. castaneum*.

Table 2 Short-exposure (10 min) efficacy of three insecticides on *Tribolium castaneum,* when applied in correct and incorrect label-doses on porous (filter paper) and nonporous surface (glass).

	% Mortality ± SD after 102 h					
Dose	**Correct dose**		**Over-dosage 2x**		**Under-dosage 5x**	
Surface	**Paper**	**Glass**	**Paper**	**Glass**	**Paper**	**Glass**
K-Othrine	1.7±3.7	10±10	17±11	37±39	6.,7±9.4	12±17
Ficam	100±0	100±0	100±0	100±0	0±0	100±0
Actellic	1.7±3.7	100±0	3.3±4.7	100±0	0±0	100±0

Table 3 Short-exposure (10 min) efficacy of three insecticides on *Sitophilus oryzae*, when applied in correct and incorrect label-doses on porous (filter paper) and nonporous surface (glass).

	% Mortality ± SD after 102 h					
Dose	**Correct dose**		**Over-dosage**		**Under-dosage**	
Surface	**Paper**	**Glass**	**Paper**	**Glass**	**Paper**	**Glass**
K-Othrine	97±4.7	100±0	100±0	100±0	85±9.6	100±0
Ficam	100±0	100±0	100±0	100±0	63±22	100±0
Actellic	43±18	100±0	50±27	100±0	43±29	100±0

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