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Activity of two deltamethrin formulations on different surfaces against rice weevil, *Sitophilus oryzae* (L.)

Elazar Quinn, Anatoly Trostanetsky, Mula Nega, Rafi Hefetz, Moshe Kostyukovsky

Department of Food Quality and Safety, ARO, Volcani Center, Rishon LeZion 7505101, Israel,
elazar@volcani.agri.gov.il
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Abstract

Several methods are used to control stored product insects. The spraying of empty structures with insecticides, prior to the introduction of produce, is an important method for preventing development of insects. It is known that insecticide activity varies according to the various sprayed surfaces. In this study, the activity of deltamethrin was examined on concrete and plastic surfaces. Deltamethrin is a synthetic pyrethroid, active by contact against a variety of insects; applied in Israel in two formulations: KESHET 2.5% EC and BUNGY 1.5% SC (ADAMA Makhteshim Ltd.). Adults of the rice weevil, *Sitophilus oryzae* (L.), served as target insect in all experiments. The research was carried out in plastic Petri dishes and in Petri dishes with layer of concrete. Deltamethrin (KESHET 2.5% EC) was applied in water solution in doses of 0.02, 0.1, 0.5 g/m^2. Without concrete, complete mortality of *S. oryzae* was obtained at a concentration of 0.02 g/m^2, whereas in concrete plates, no mortality was found in all 3 concentrations. In contrast, deltamethrin (BUNGY 1.5% SC) in doses of 0.1 g/m^2, caused 100% mortality with and without concrete layer. The same results were found in the commercial warehouse. No difference in efficiency was found between the spraying methods: airbrush (Sparmax DH-125) or dripping by pipette. The results show that the efficacy of warehouse spraying by deltamethrin depends on its formulation.

Keywords: deltamethrin, stored product insects, treated surfaces, concrete, suspension, emulsion.

1. Introduction

The control of stored product insects, which cause serious damage to stored agricultural produce, is achieved by a combination of several methods. The use of protectants is an important and widespread method for preventing the development of stored product insects as an integral part of pest control practice. Protectants are applied by spraying incoming grains and empty warehouses, prior to produce introduction; in order to disinfest insect population on surface and cracks. Using residual materials can reduce and slow insects' infestation and reduce or eliminate the need for further control treatments. Surface treatments are applied as liquid contact insecticides on different types of surfaces (Arthur and Subramanyam, 2012). Floor and walls of grain warehouses are usually made of concrete. The surface of concrete is porous and alkaline, so when the insecticides are applied to concrete, hydrolysis and rapid degradation occur (Arthur, 1994; Jain and

Yadav, 1989). Hence, insecticides efficacy may depend on its formulation. Deltamethrin is synthetic pyrethroid, exceptionally potent against the whole spectrum of stored product pests (Snelson, 1987). Using deltamethrin can be effective as grain protectant or as surface treatment, singly or in combination with other insecticides, to control stored product insects. Contact toxicity of deltamethrin was found highly effective against *Tribolium castaneum* (Herbst), *Sitophilus oryzae* (L.), and *Rhyzopertha dominica* (Fab.) (Paudyal et al., 2016). Several studies which examined deltamethrin efficacy on various surfaces reported that wettable powder (WP) formulation was more effective than emulsifiable concentrate (EC) (Jain and Yadav, 1989). Deltamethrin is applied in Israel by two formulations: KESHET 2.5% EC and BUNGI 1.5% SC (ADAMA Makhteshim Ltd.). In this study, the activity of these two formulations was examined on concrete and smooth surfaces, under laboratory conditions and in commercial warehouses.

2. Materials and methods

Insects

Sitophilus oryzae (L.), *Rhyzopertha dominica* (Fab.) and *Tribolium castaneum* (Herbst) cultures have been reared under laboratory conditions for many years without any contact with insecticides. *S. oryzae* and *R. dominica* were reared on wheat grain, *T. castaneum* was reared on wheat flour. All these insects were maintained in 0.8L glass jars with paper covers and bred at 30±0.5^{0}C and 65±5% r.h. in dark.

Chemicals

The deltamethrin for the experiments was applied in two formulations: KESHET (2.5% EC, ADAMA Makhteshim Chemical Plants Ltd) and BUNGI (1.5% SC, ADAMA Makhteshim Chemical Plants Ltd).

Laboratory Experiment

In a laboratory experiment, deltamethrin formulations were examined in Petri dishes (diameter 9 cm). Plates without concrete (plastic) and plates with concrete were used. Individual concrete arenas in Petri dishes were made by mixing cement (42.5N II/A–LL) - sand - water (1:1:0.5). About 30 grams of the mixture was added in each Petri dish. Four days later, plates with concrete layers were ready to be used. The required concentrations of insecticides were obtained by dilution by tap water. About 0.62 ml of mixture (100 ml/m^2) was sprayed by airbrush (Sparmax DH-125), or dripping by pipette (approximately 40 drops per plate) to each Petri dish. Tap water was used as control.

For studying the effect of alkaline concrete, flush water from fresh concrete surface was used. 15 ml of tap water were added into each Petri dish with a concrete layer, and after one hour the water was removed from the dishes, with a pipette. About 10 ml of flush water was obtained from each Petri dish.

In all laboratory experiments, ten adults of *S. oryzae, R. dominica* or *T. castaneum* were exposed in Petri dishes with/without concrete layer, without food, in each probe. The plates were stored in the dark at 30±0.5^{0}C and 65±5% r.h. Insect mortality was recorded after 2 and 24 hours of exposure. Each treatment was replicated 3 times.

Warehouse experiments

For several years, local grains are stored in warehouses in the south of Israel. Before inserting the new wheat harvest, crop residue was removed from the warehouses and a mixture of ACTELLIC 50 EC, KESHET 2.5 EC and water was sprayed in the warehouses. The concentration of ACTELLIC 50 EC in the mixture was constant (1.0%), and the concentration of KESHET 2.5 EC increased from 1.0 to 3.0%. In a certain year, during commercial treatment, the warehouses were sprayed with only 4% KESHET 2.5 EC in water; working mixture consumption at 100 ml/m^2. A day after the spraying, the effectiveness of the treatment was tested. Adults *S. oryzae* (10 insects in each probe) were put on

various treated structures, and their movements were limited within lower part of Petri dishes which were attached to the surface with duct tape (14 probes). After 24 hours, the insects were transferred to Petri dishes which were put in incubator and their mortality was recorded the following day.

To test the efficiency of the spraying in storage facilities with two different deltamethrin formulations, 14×14cm squares (~0.02m^2) were marked on concrete walls and insecticides were sprayed by airbrush (Sparmax DH-125) on the marked squares. Ten adult *S. oryzae* were transferred onto the treated squares. The movement of insects was limited to a net that was attached with duct tape. After 24 hours, the insects were transferred from concrete walls to Petri dishes and their mortality was recorded. Each treatment was replicated 3 times.

Statistical analysis

A one-way analysis of variance (ANOVA) was used to compare percent of insect mortality. The Tukey Multiple Range test was used to compare mean values. (JMP Pro 13.0.0., 2016).

3. Results

Exposing stored product insects to KESHET 2.5% EC in concentration 20 mg/m^2, caused after 24 hours of exposure the following results: 100% mortality of *S. oryzae* and *T. castaneum*, and 23.3% mortality of *R. dominica*; and in concentration 100 mg/m^2 - 100% mortality of *S. oryzae, R. dominica* and *T. castaneum* (Tab. 1).

Tab. 1 Contact effect of 2.5 EC KESHET on plastic surface against stored product insects.

Spray*	Dose of deltamethrin g/m^2	Mortality (%), after 24 hours exposure		
		S. oryzae	*T. castaneum*	*R. dominica*
0.8% KESHET 2.5EC	0.02	100 A	100 A	23.3±8.8 B
4.0% KESHET 2.5EC	0.1	100 A	100 A	100 A
20.0% KESHET 2.5EC	0.5	100 A	100 A	100 A
Control	0	0 C	0 C	3.3±3.3 C

* - Tap water was used for dilution of commercial concentrates of deltamethrin and as control. 0.62ml of mixture (100 ml/m^2) was transferred at dripping by pipette (approximately 40 drops per plate) to each plastic Petri dish.

** - Ten adult insects were introduced in each sample. Each treatment was triplicate. Values are the means ± SEM. Values represented with the same letter are not significantly different one from the other.

In the commercial treatment in the warehouse, after 24 hours exposure, mortality of *S. oryzae* in KESHET 2.5EC depended on the surface type and on the location of treatment in the warehouse. Mortality on galvanized steel in all tests was 100%; mortality on concrete was 20 -100%. Control mortality in the untreated warehouse was 0 - 20%.

In the laboratory test on concrete surface, KESHET 2.5% EC was not effective, even in deltamethrin rate of 500 mg (AI)/m^2. In contrast, BUNGI (1.5% SC, ADAMA Makhteshim Chemical Plants Ltd), in concentration of 100 mg (AI)/m^2 caused 100% mortality of *S. oryzae, R. dominica* and *T. castaneum*. No significant difference in efficiency were found between the spraying methods: airbrush (Sparmax DH-125) or dripping by pipette (approximately 40 drops per plate) (Tab. 2).

In the warehouse test, on concrete surface, KESHET 2.5% EC in concentration 100 mg (AI)/m^2 was not effective. However, BUNGI (1.5% SC, ADAMA Makhteshim Chemical Plants Ltd) in same concentration caused 100% mortality of *S. oryzae* (Tab. 3).

Tab. 2 The effect of two deltamethrin formulations on concrete against stored product insects.

Spray*	Mortality (%)** after 24 hours exposure		
	S. oryzae	*T. castaneum*	*R. dominica*

	Dose of deltamethrin g/m²	Airbrush	Pipette	Airbrush	Pipette	Airbrush	Pipette
4.0% KESHET 2.5EC	0.1	3.3±3.3 B	0 B	0 B	0 B	-	-
20.0% KESHET 2.5EC	0.5	0 B	16.7±16.7 B	0	3.3±3.3 B	-	-
6.7% BUNGI 1.5SC	0.1	100 A	100 A	100 A	100 A	100 A	90.0±5.8 A
33% BUNGI 1.5SC	0.5	100 A	100 A	100 A	100 A	100 A	93.3±3.3 A
Control	0	3.3±3.3 B	0 B	0 B	0 B	0 B	0 B

* -Tap water was used for dilution of commercial concentrates of deltamethrin and as control. 0.62ml of mixture (100 ml/m²) was transferred on each prepared Petri dishes with concrete by dripping by pipette (approximately 40 drops per plate) or by spraying with airbrush.

** - Ten adult insects were introduced in each sample. Each treatment was triplicate. Values are the means ± SEM. Values represented with the same letter are not significantly different one from the other.

Tab. 3 The effect of two deltamethrin formulations in dose 0.1 g/m² against *S. oryzae* on concrete wall in warehouse.

Spray*	Mortality (%)** 24 hours after exposure	
	2 hours of exposure	24 hours of exposure
4.0% KESHET 2.5EC	6.7±6.7 B	13.3±8.8 B
6.7% BUNGI 1.5SC	100 A	100 A
Control	6.7±6.7 B	11.2±0.7 B

* - Tap water was used for dilution of commercial concentrates of deltamethrin and as control. 2.0 ml of mixture (100 ml/m²) was sprayed by airbrush on concrete wall in surface area, at size of 14×14 cm. The temperature in warehouse was 5 – 15⁰C.

** - Ten adult insects were introduced in each sample. Each treatment was triplicate. Values are the means ± SEM. Values represented with the same letter are not significantly different one from the other.

For studying the effect of alkaline concrete, flush water from fresh concrete surface and KESHET 2.5% EC in low concentration 10 mg (AI)/m² were used. Influence of concrete alkaline on efficacy of 2.5EC KESHET was found.

Tab. 4 Influence of concrete alkaline on effectivity of 2.5EC KESHET against *S. oryzae*.

Spray*	Surface	Mortality (%) ** 24 hours after exposure 2 hours of exposure	24 hours of exposure
0.4% KESHET 2.5EC in tap water	**Plastic**	83±3.3 AB	96.7±3.3 A
0.4% KESHET 2.5EC in concrete water* **	**Plastic**	0 C	73±3.3 B
0.4% KESHET 2.5EC in tap water	**Concrete**	0 C	0 C

* - 0.62ml of mixture (100 ml/m²) was sprayed by airbrush to each Petri dishes with/without concrete; dose of deltamethrin 0.01 g/m²

** - Ten adult insects were introduced in each sample. Each treatment was triplicate. Values are the means ± SEM. Values represented with the same letter are not significantly different one from the other.
*** - pH concrete flush water 12.5.

4. Discussion

Deltamethrin is a broad-spectrum synthetic pyrethroid insecticide with contact activity that is widely used to control stored product insects. In this study, emulsifiable concentrate of deltamethrin (KESHET 2.5% EC, ADAMA Makhteshim Chemical Plants Ltd), which were applied on Petri dishes, in concentration 20 mg/m^2, was very effective .

According to Paudyal et al. (2016), who used technical grade deltamethrin in ethanol on glass Petri dishes, LD_{95} for *S. oryzae* was 123.6 mg/m^2 (70.9–288.3), for *R. dominica* it was 121.3 mg/m^2 (74.4–233.6) and 57.8 mg/m^2 (43.2–83.0) for *T. castaneum*. The differences in the efficacy of deltamethrin are due probably to the fact that in our study we used a commercial product, rather than a technical grade deltamethrin, and insect's strains variability.

In our warehouse experiment, the efficacy of commercial treatment by spray KESHET 2.5% EC in rate of 100 mg (AI)/m^2 on concrete, against *S. oryzae*, varied in different parts of the warehouse.

Suspension concentrate formulation of deltamethrin (Centynal™) and chlorpyrifos-methyl + deltamethrin (Storcide™ II) are used in USA (Sehgal and Subramanyam, 2014, Sehgal et al., 2014); mix pirimiphos-methyl (ACTELLIC 50 EC) + deltamethrin (KESHET 2.5 EC) - are used in Israel.

In our laboratory experiments on concrete, KESHET 2.5% EC was not effective. In contrast, the new commercial formulation of deltamethrin, BUNGI (1.5% SC, ADAMA Makhteshim Chemical Plants Ltd), in concentration of 100 mg (AI)/m^2 caused 100% mortality of *S. oryzae, R. dominica* and *T. castaneum*. Similar results were obtained when testing the two formulations of deltamethrin in a warehouse.

It is a known fact that pyrethroid efficacy may be dependent on formulation. Jain and Yadav (1989) reported differences in efficacy of an emulsifiable concentrate (EC) and wettable powder (WP) formulations. In the same study, adult insects exposed to deltamethrin were applied at 10 mg (AI)/m^2 on various surfaces including concrete. WP formulation was more effective than the EC formulation on concrete.

According to Arthur (1997), 0.05% deltamethrin dust has potential to knockdown or kill *T. castaneum* and *R. dominica* after 24 h exposure on concrete, and has potential as a residual treatment in food storage facilities. However, use of dust and WP is inconvenient in practice. Suspension combines effectiveness of dust/WP and all the performance benefits of emulsions. Suspension concentrates of deltamethrin: Centynal (Wellmark Internatonal, Schaumburg, IL, 37mg (AI)/ml)) and Suspend® SC 4.75% AI, were effective against stored product insects. Centynal at 20 mg (AI)/m^2 on concrete was effective against adults of *R. dominica*, *T. castaneum* and *Oryzaephilus surinamensis* (L.) causing 100% mortality of laboratory strains (Sehgal and Subramanyam, 2014); Suspend® SC 4.75% AI at 24 mg (AI)/m^2 on concrete caused 100% mortality of adults and larvae of laboratory strains of *Trogoderma granarium* (Everts) (Ghimire et al., 2017).

Factors such as surface activity, surface pH, porosity and transfer from carrier to insect may play a role in the different effectiveness of two deltamethrin preparations on concrete. It was observed, that there was an influence of concrete alkaline on efficacy of 2.5EC KESHET. However, the decline in efficiency of KESHET 2.5% EC on concrete cannot be explained by basic pH only. The results show that the efficacy of deltamethrin treatment depends on its formulation and on the sprayed surfaces.

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Evaluation of two new insecticide formulations based on inert dusts and botanicals against four stored-grain beetles

Zlatko Korunic[1], Paul G. Fields[2]

1. Diatom Research and Consulting Inc., 14 Tidefall Dr., Toronto ON, M1W 1J2, Canada, zkorunic@rogers.com
2. Morden Research and Development Centre, Agriculture and Agri-Food Canada, paul.fields@agr.gc.ca
DOI 10.5073/jka.2018.463.176

Extended Abstract

Diatomaceous earth (DE) is toxic to insects because it absorbs their cuticular waxes causing insects to die from desiccation. DEs are obtained from geological deposits around the world, are skeletons of diatoms, and are mainly made up of SiO_2, with very low mammalian toxicity They can be applied with approximately the same technology as other powder insecticides (Korunic, 1998; Subramanyam and Roesli, 2000). Several DEs are effective at doses of 500 ppm or higher. However, these doses cause unwanted effects on grain quality and flowability and their application for direct mixing with grain has limited acceptance by the grain industry (Korunic et al., 1996; Subramanyam and Roesli, 2000). Therefore, it is essential to develop formulations that are effective at lower doses of DE. One of the solutions is to combine DE with other substances, primary with botanicals (Athanassiou and Korunic, 2007; Athanassiou et al., 2009). Our objective was to develop effective insecticides using as much as possible Generally Recognized as Safe (GRAS) compounds that would not significantly reduce grain flow or test weight.

We developed two new insecticide formulations that combine: diatomaceous earth (DE), silica gel, pyrethrin, piperonyl butoxide (PBO) and dill essential oil (F2Z) or with these same ingredients and disodium octaborate tetrahydrate (F3DOTZ). Silica gel (Sipernat® 50 S) is synthetic amorphous silicon dioxide and, has similar mode of action as DE. Amorphous silicon dioxide is (GRAS) and, is used as a food additive. Pyrethrin is one of the most common botanical insecticides. To prevent the recovery of insects after the treatment, the pyrethrin formulations contain a synergist, most frequently piperonyl butoxide (PBO) (Ware and Whitacre, 2004). Dill essential oil is extracted from the seeds or leaves/stems of the dill (*Anethum sowa* and *A. graveolens*). Dill oil is known as a natural synergist for pyrethrin (Liu et al., 2014). Disodium octaborate tetrahydrate (DOT) is a naturally occurring mineral salt commonly called borate or sodium borate. It is used to treat lumber and other wood products to control fungi, termites, and other wood infesting pests (Ware and Whitacre, 2004). DOT is effective against *Sitophilus oryzae* (L.) and does not reduce bulk density as much as DE reduces bulk density (Korunic et al., 2017).

Sitophilus oryzae L., *S. granarius* (*L.*) (Coleoptera: Curculionidae*),* and *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae) and one external feeder*, Tribolium castaneum* Herbst (Coleoptera: Tenebrionidae*)* were held on clean wheat (13.5% moisture) treated with different doses of the insecticides and held at 28 ± 1ºC and 60 ± 5 % RH for 3, 5 and 7 days, and then held for progeny emergence. In the series of three experiments both formulations were applied either as dusts or as wettable powders, F2Z at 150 ppm and F3DOTZ at 200 ppm.

After 3 days, with powders and wettable powder of F2Z and F3DOTZ formulations there was 100% mortality for *S. oryzae* and *R. dominica*. After 7 days, the mortality of *T. castaneum* was from 96 to