PS4-9 – 6200

Effects of several contact insecticides on adults of three *Sitophilus* species

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Abstract

Toxicity of the contact insecticides dichlorvos, malathion, chlorpyrifos-methyl, pirimiphos-methyl, deltamethrin and bifenthrin was tested on adults of granary weevil (*Sitophilus granarius* L.), rice weevil (*S. oryzae* L.) and maize weevil (*S. zeamais* Motsch.) normally susceptible to insecticides. The adults were exposed to filter paper impregnated with each insecticide for 3, 6, 24 and 48 hours and tested with a modified FAO method. Based on the mortality data acquired, toxicity parameters (LD_{50}, LD_{95} and slopes of *ld-p* lines) could be calculated for the 3 h exposure period only for dichlorvos in the granary weevil test. The calculation was possible for all weevil species after 6 h of exposure to dichlorvos and bifenthrin, and only after 24 h exposure to malathion, chlorpyrifos-methyl, pirimiphos-methyl and deltamethrin. Comparing the toxicity parameters, all insecticides were found to be most toxic to granary weevil adults. Chlorpyrifos-methyl and deltamethrin were the most and malathion the least toxic to *S. granarius* adults. The most toxic to *S. oryzae* adults were bifenthrin and dichlorvos, and the least toxic pirimiphos-methyl, while dichlorvos was the most and malathion least toxic to *S. zeamais* adults. Dichlorvos showed similar toxicity to all weevil species tested after 24 h and 48 h. After a 48 h exposure period, malathion and pirimiphos-methyl were around 2 x less toxic to rice and maize weevils than to granary weevils at the LD_{50} level, while the respective relationship at the LD_{95} was 2.1 x and 2.8 x, and 3.8 x and 4.0 x. Chlorpyrifos-methyl was 3.9 x and 6.0 x less toxic to rice and maize weevils at the LD_{50}, and 18.7 x and 10.1 x at the LD_{95}. Deltamethrin was 5.5 x and 10.8 x less toxic to rice and maize weevils at the LD_{50}, and 7.7 x and 6.4 x at the LD_{95}. Bifenthrin was 2.8 x and 3.3 x less toxic to rice and maize weevils at the LD_{50}, and 1.2 x and 1.9 x at the LD_{95}.

Key words: *Sitophilus granarius*; *Sitophilus oryzae*; *Sitophilus zeamais*; Contact insecticides; Treated filter paper.

Introduction

Granary weevil (*Sitophilus granarius* L.), rice weevil (*S. oryzae* L.) and maize weevil (*S. zeamais* Motsch.) are weevil species currently widespread in Serbia and other regions of former Yugoslavia. Granary weevil used to be the main insect pest of whole cereal grains before modernized commercial storage systems were introducted and it is still the most widespread weevil species in stockpile storage facilities. However, rice weevil has lately become the number one pest of whole grains in modern commercial storage systems.

All three *Sitophilus* species are able to cause

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considerable losses to stored cereals (Rees, 1996) and to stimulate conditions favourable for the appearance of various microorganisms, including toxigenic fungi (Levic et al., 2004).

Apart from taking preventive measures in stored grains protection, chemicals are the other most widespread method of pest control in storage systems in Serbia (Kljajic, 2004). Concerning fumigants, two formulations based on aluminium phosphide and one based on magnesium-phosphide have been registered in our country, while contact insecticides in current use include formulations of malathion, pirimiphos-methyl and synergized or non-syndergized deltamethrin for treatments of cereals, and dichlorvos for treatments of vacant storage areas (Mitic, 2004).

This investigation aimed to compare the effects of several contact insecticides listed above, which are registered in Serbia, in laboratory tests on three *Sitophilus* species. Effects of chlorpyrifos-methyl, which has been in use for the past 20 years, and bifenthrin, which has not yet been registered, were also tested.

The results of our investigation of contact insecticides, all except bifenthrin, against *S. granarius* population of normal susceptibility to insecticides have been presented in studies of population susceptibility in various storage facilities (Kljajic and Peric, 2006).

Materials and methods

Test insects

Adults of granary weevil (*Sitophilus granarius* L.), rice weevil (*S. oryzae* L.) and maize weevil (*S.zeamais* Motsch.) were tested. The granary weevil population has been reared in the insectarium of the Pesticide and Environmental Research Centre for the past 15 years and the other two populations for 10 years without exposure to insecticides. All weevils are reared according to methods proposed by Harein and Soderstrom (1966), and Davis and Bry (1985). Granary and rice weevils grow on whole grain soft wheat containing 12 % m.c., under 25 ± 1 °C temperature and 60 ± 5 % RH.

Insecticides applied

The following technical grade insecticides were used in toxicity tests: dichlorvos (98 %), malathion (96 %), chlorpyrifos-methyl (97%), deltamethrin (98 %), bifenthrin (94.7 %) and pirimiphos-methyl as the product Actellic 50 EC with 50 % a.i.

Bioassay procedure

Toxicity was determined after the application of each insecticide to filter paper and exposure of weevil adults according to a method described by Haliscak and Beeman (1983), which is consistent with the FAO method 15 (Busvine, 1980). The insecticides were diluted in a mixture of hexane, acetone and sunflower oil (3:1:1 ratio) and applied at 0.5 mL rate with four replicates per concentration on filter paper discs using a procedure described by Kljajic and Peric (2006).

Dichlorvos toxicity was determined after 3, 6 and 24 h of exposure of weevils to the impregnated filter paper, and that of the other insecticides after 6, 24 and 48 h.

Mortality data for weevils treated on filter papers were corrected for mortality in the corresponding controls using Abbott's (1925) formula. The corrected mortality data were processed by probit analysis according to a method described by Finney (1971) and using a computer software developed by Raymond (1985).

Statistical significance of differences in toxicity indicators for the insecticides investigated was assessed based on the overlapping/non-overlapping of intervals of confidence.

Results

All insecticides tested in this investigation were found to increase toxicity to adults of all three *Sitophilus* species with the duration of exposure to impregnated filter paper. Based on

the mortality data, it was possible to calculate toxicity parameters (LD_{50}, LD_{95} and slopes of *ld-p* lines) after 3 h of exposure only for granary weevils treated with dichlorvos. The same parameters could be calculated for all weevil species after 6 h of exposure to dichlorvos and bifenthrin, and for granary and maize weevils in deltamethrin tests. Toxicity parameters of the other insecticides tested (malathion, chlorpyrifos-methyl and pirimiphos-methyl) could be calculated for all three weevil species only after 24 h exposure, and the situation was the same with rice weevil in deltamethrin test.

Chlorpyrifos-methyl and deltamethrin were the most toxic insecticides to granary weevils regarding all periods of exposure to treated filter paper, while the least toxic was malathion (Table 1). Dichlorvos clearly stood out in terms of initial toxicity. At the LD_{50}, differences in toxicity over the different periods of exposure were statistically significant for all insecticide except deltamethrin after 6 and 24 h. However, at the LD_{95}, no significant differences were found in dichlorvos toxicity after 3 and 6 h, malathion after 24 and 48 h, and deltamethrin and bifenthrin after 6 and 24 h.

According to most parameters, bifenthrin and dichlorvos, followed by chlorpyrifos-methyl, were most toxic to rice weevil adults, and pirimiphos-methyl and malathion least toxic (Table 2). At the LD_{50}, differences in toxicity over different exposure periods were significant for all insecticides, while no significant difference was found at the LD_{95} level only for dichlorvos after 6 and 24 h exposure.

The most toxic insecticide to maize weevil was dichlorvos, and the least malathion, followed by pirimiphos-methyl (Table 3). Differences in toxicity for this weevil species were significant between different exposure periods of all insecticides at the LD_{50}, while no significant difference in toxicity was found at the LD_{95} for dichlorvos after 6 and 24 h, pirimiphos-methyl after 24 and 48 h and between all exposure periods of bifenthrin.

Table 1. Insecticides toxicity to *Sitophilus granarius* adults after different periods of contact with impregnated filter paper.

Insecticide	Evaluation after (h)	LD_{50} (µg /cm^2) FL (0.05)	LD_{95} (µg /cm^2) FL (0.05)	Slope of *ld-p* line (±SE)
Dichlorvos	3	7.02 (6.37-7.67)	18.07 (15.34-22.49)	3.98 ± 0.35
	6	4.42 (3.90-4.81)	13.00 (10.92-16.25)	3.48 ± 0.28
	24	1.95 (1.82-2.21)	5.33 (4.42-6.50)	3.81 ± 0.29
Malathion	24	8.32 (6.11-11.31)	13.00 (7.80-22.23)	8.49 ± 2.19
	48	3.51 (2.99-3.90)	9.36 (8.06-11.31)	3.82 ± 0.41
Chlorpyrifos-methyl	24	0.94 (0.90-0.99)	1.56 (1.43-1.82)	7.27 ± 0.64
	48	0.60 (0.55-0.64)	1.08 (0.97-1.23)	6.34 ± 0.59
Pirimiphos-methyl	24	7.27 ± 0.64	4.16 (3.90-4.55)	7.36 ± 0.75
	48	7.67 (7.28-8.19)	12.87 (11.70-14.82)	6.96 ± 0.60
Deltamethrin	6	1.56 (1.30-1.69)	9.75 (7.67-13.13)	2.05 ± 0.13
	24	1.10 (0.86-1.43)	6.89 (4.29-11.44)	2.06 ± 0.19
	48	0.43 (0.36-0.49)	2.60 (2.08-3.38)	2.12 ± 0.16
Bifenthrin	6	4.83 (4.35-5.48)	19.55 (14.49-30.80)	2.71 ± 0.29
	24	1.73 (1.51-1.97)	12.85 (9.80-17.75)	1.89 ± 0.13
	48	0.96 (0.83-1.12)	8.79 (6.70-12.13)	1.72 ± 0.11

Table 2. Insecticide toxicity to *Sitophilus oryzae* adults after different periods of contact with impregnated filter paper.

Insecticide	Evaluation after (h)	LD_{50} (µg /cm^2) FL (0.05)	LD_{95} (µg /cm^2) FL (0.05)	Slope of *ld-p* line (±SE)
Dichlorvos	6	20.57 (19.57-21.73)	37.06 (32.90-44.14)	6.43 ± 0.66
	24	5.54 (4.79-6.55)	34.56 (24.36-56.91)	2.07 ± 0.20
	48	0.97 (0.86-1.10)	3.38 (3.07-5.32)	2.74 ± 0.23
Malathion	24	14.64 (13.44-15.97)	39.28 (33.30-49.11)	3.83 ± 0.33
	48	7.01 (6.21-7.75)	20.17 (17.23-25.19)	3.58 ± 0.36
Chlorpyrifos-methyl	24	4.61 (4.19-5.07)	22.12 (17.81-29.32)	2.41 ± 0.17
	48	2.36 (2.12-2.63)	10.62 (8.69-13.76)	2.52 ± 0.18
Pirimiphos-methyl	24	17.57 (16.63-18.64)	43.03 (37.76-50.91)	4.23 ± 0.29
	48	8.44 (7.78-9.10)	27.68 (23.71-33.95)	3.20 ± 0.24
Deltamethrin	24	5.81 (4.80-6.77)	61.76 (43.51-103.47)	1.60 ± 0.16
	48	2.38 (2.00-2.78)	20.00 (15.54-27.13)	1.78 ± 0.12
Bifenthrin	6	10.76 (9.63-12.40)	43.53 (32.06-68.16)	2.71 ± 0.27
	24	4.07 (3.70-4.48)	16.39 (13.42-21.39)	2.72 ± 0.21
	48	2.67 (2.42-2.95)	10.14 (8.50-12.71)	2.84 ± 0.20

Table 3. Insecticide toxicity to *Sitophilus zeamais* adults after different periods of contact with impregnated filter paper.

Insecticide	Evaluation after (h)	LD_{50} (µg /cm^2) FL (0.05)	LD_{95} (µg /cm^2) FL (0.05)	Slope of *ld-p* line (±SE)
Dichlorvos	6	5.42 (4.79-6.10)	24.94 (19.75-34.24)	2.48 ± 0.21
	24	3.60 (3.19-4.04)	17.87 (14.54-23.12)	2.36 ± 0.16
	48	2.32 (2.05-2.64)	13.63 (10.65-18.71)	2.14 ± 0.15
Malathion	24	10.62 (9.60-11.71)	53.81 (35.45-58.33)	2.67 ± 0.22
	48	7.17 (6.42-7.92)	26.11 (21.60-33.90)	2.93 ± 0.26
Chlorpyrifos-methyl	24	5.99 (5.43-6.49)	20.94 (17.04-28.51)	3.02 ± 0.32
	48	3.57 (3.28-3.85)	10.87 (9.57-12.71)	3.40 ± 0.22
Pirimiphos-methyl	24	10.36 (9.56-11.20)	35.04 (29.96-42.88)	3.11 ± 0.22
	48	3.77 (2.78-4.59)	29.32 (21.19-50.55)	1.84 ± 0.25
Deltamethrin	6	24.87 (22.06-29.63)	90.53 (63.98-158.58)	2.93 ± 0.36
	24	6.36 (5.81-6.92)	28.54 (24.52-34.29)	2.52 ± 0.14
	48	4.65 (4.26-5.06)	16.64 (14.26-20.19)	2.97 ± 0.19
Bifenthrin	6	9.26 (8.60-10.09)	26.23 (20.91-37.52)	3.64 ± 0.43
	24	4.85 (4.42-5.30)	18.96 (15.97-23.56)	2.78 ± 0.19
	48	3.15 (2.81-3.51)	16.91 (13.65-22.22)	2.25 ± 0.19

Discussion

Comparing all toxicity parameters examined, it is evident that all insecticides tested were most toxic to granary weevil adults. All insecticides were significantly more toxic to granary weevils than to rice weevils at the LD_{50} level in all periods of exposure, while no significant difference was found at the LD_{95} only for bifenthrin after 24 and 48 h. The least difference in toxicity to the two species was found between bifenthrin and malathion, and the highest between chlorpyrifos-methyl and deltamethrin. After 24 h exposure at the LD_{95}, chlorpyrifos-methyl was 14.2 x more toxic to granary weevil than to rice weevil, and deltamethrin around 9.0 x.

There were no significant differences between granary and maize weevils in the toxicity of dichlorvos after 24 and 48 h exposure at the LD_{50}, malathion after 24 h and pirimiphos-methyl after 48 h. At the LD_{95} level, no difference in toxicity was found for dichlorvos and bifenthrin after 6 and 24 h. The lowest difference in toxicity between these two weevil species were found for bifenthrin and dichlorvos, and the highest for deltamethrin and chlorpyrifos-methyl. For instance, deltamethrin was 15.9 x more toxic to granary weevil than to maize weevil at the LD_{50} after 6 h exposure, while chlorpyrifos-methyl was more toxic to granary weevil 13.4 x at the LD_{95} after 24 h.

Other authors have also reported significant differences in the toxicity of contact insecticides to various *Sitophilus* species. Williams et al. (1978), for instance, found that chlorpyrifos-methyl was 3.5 x more toxic to granary weevil than to rice weevil at the LC_{50} level. Arthur (1994) also found the toxicity of chlorpyrifos-methyl and deltamethrin to be higher to maize weevil than to rice weevil.

In this research, we detected a high potential of bifenthrin in terms of its toxicity to all three weevil species investigated. The findings are consistent with the high efficacy of that insecticide, applied individually or in combination with malathion, in controlling rice and maize weevis, as well as some other species of the *Coleoptera* order reported in several European countries (Wilkin et al., 1999).

Acknowledgement:

Financial support for this study was provided by the Serbian Ministry of Science and the Environment.

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