Laboratory evaluation of diatomaceous earth against main stored product insects

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Abstract

The sensitivity of the main external and internal stored product insect pests to the commercial formulation of Detia Degesch Diatomaceous Earth – DDDE - Inerto (DE) was studied in laboratory experiments. The tested insects were adults of internal feeders *Sitophilus oryzae Rhyzopertha dominica* and external feeders *Oryzaephilus surinamensis*, *Tribolium castaneum*, and larvae (third instar) of *T. castaneum*. The DE was applied to wheat grain of 12% moisture content at concentrations of 0.5, 1.0, 2.0 and 4.0 g/kg of grain. The treated and untreated (control) grain were kept at 28˚C and 65 ± 5% r.h. The numbers of dead and survived insects were counted two, three and four weeks after treatment. The number of adult progeny was counted nine weeks after treatment. At a concentration of 0.5 g/kg, mortality of *S. oryzae* and *O. surinamensis* after three weeks of exposure to DE were 92 and 86%, respectively. In contrast, mortality of *T. castaneum* and *R. dominica* adults was 3 and 37%, respectively. Progeny production of *O. surinamensis* and *T. castaneum* at a concentration of 2 g/kg was negligible, since only few individuals were recorded nine weeks after treatment, in comparison with the high progeny production in the control grain. The progeny of *S. oryzae* was also reduced. In contrast, for *R. dominica* was reduced only twice, in comparison with the control. In the case of *T. castaneum* larvae, at a concentration of 2 g/kg, after 4 weeks of exposure, 37% of the larvae emerged to adults, compared with 95% in control. Nine weeks after treatment, the number of F_1 adults was 100% suppressed. DE efficacy was similar at 4 g/kg. Based on the findings of the present study, the efficacy of the tested DE was influenced by DE concentration, insect species, developmental stage and exposure interval to the treated commodity.

Keywords: Diatomaceous earth, Stored product insects, Wheat grain

1. Introduction

The use of contact insecticides as grain protectants against stored product insect pests is a common and effective treatment in Israel and worldwide. However, the demands for residue-free food and environmental safety, as well as development of resistant insect pest populations to residual insecticides, have led to attempts to find non-toxic to human and environmentally friendly alternative protectants. Diatomaceous earth (DE) is known as one of the most promising alternatives to traditional residual insecticides (Athanassiou et al., 2003; 2004; 2007; 2008; Athanassiou and Korunic, 2007; Vayias and Stephou, 2009). DE is a non-toxic, safe, natural origin material with a unique, non-chemical mode of action against insects which die through desiccation (Korunic, 1998; Subramanyam and Roesli, 2000). Today, DE is in wide use for various products and processes, from toothpaste to cigars, plastics to paprika, filter media in swimming pools to home fish tanks, as well as insect and parasite control in animals and grain. The efficacy of commercial formulations of DE has been proved for a number of insect species on various stored grains. However, the DE efficacy often varies with the formulation, treated commodity and other factors (Desmarchelier and Dines, 1987; Subramanyam et al., 1994; Subramanyam and Roesli, 2000; Athanassiou et al., 2003; Vayias and Athanassiou, 2004; Athanassiou and Kavallieratos, 2005; Athanassiou et al., 2003; 2004; 2007; 2008; Kavallieratos et al., 2005).

In the current study, the laboratory evaluation of the sensitivity of the main external and internal stored product insect pests to commercial formulation of DE Detia Degesch Diatomaceous Earth – DDDE-Inerto (Detia Degesch GmbH) was conducted.

2. Materials and methods

The tested insects were adults of internal feeders, rice weevil, *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae), lesser grain borer *Rhyzopertha dominica* (F.) (Coleoptera: Bostrychidae), and external feeders, saw-toothed grain beetle *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae), red flour beetle *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae), as well as larvae (third instar) of *T. castaneum*. All tested insects were from laboratory-reared cultures. The DDDE was applied to wheat grain at 12% moisture content. Wheat grain lots of 3 kg were treated with DE at concentrations of 0.5, 1.0, 2.0 and 4.0 g/kg of grain. Each treatment was repeated three times (replicates). The treated and untreated (control) infestation-free grain were kept at 28˚C and 65 ± 5% r.h. Samples, of 500 g each, of treated or untreated grain were placed into glass jars of 1 lt capacity. Twenty individuals of each tested species were separately inserted into each jar, which was covered with paper to allow sufficient aeration. All jars were placed in incubators at 28˚C. The number of dead and survived insect was counted after two, three and four weeks of exposure to DE. The number of adult progeny was counted nine weeks after treatment.

3. Results

After exposure of two weeks to DE at a concentration of 0.5 g/kg, mortality of *O. surinamensis and S. oryzae* adults were 67 and 82%, respectively. In contrast, mortality of *T. castaneum* and *R. dominica* adults at the same concentration were 2 and 23%, respectively. At a concentration of 2 g/kg, adult mortality of above-mention species was 96, 93, 11 and 67%, respectively. At 4 g/kg, all (100%) adults of *O. surinamensis and S. oryzae* were dead. For *T. castaneum* and *R. dominica* adults, mortality reached 52 and 75%, respectively. Prolonged exposure to DE resulted in increased mortality of the tested species in all concentrations (Table 1).

Table 1 The efficacy of the DDDE - Inerto against adults of major stored product insects.

		Mortality (%)			
Concentration (g/kg)	**Exposure time (d)**	***Sitophilus oryzae***	***Rhyzopertha dominica***	***Tribolium castaneum***	***Oryzaephilus surinamensis***
	14	2	0	0	3
	21	2	11	2	8
0	30	8	13	2	19
	14	82	23	2	67
	21	92	37	3	86
0.5	30	94	47	5	88
	14	96	61	13	92
	21	100	77	59	97
1	30		90	82	100
	14	93	67	11	96
	21	100	84	72	10
2	30		86	96	100
	14	100	75	52	100
	21		90	96	
4	30		96	98	

Progeny production of the external feeders *O. surinamensis* and *T. castaneum*, at a concentration of 2 g/kg, was almost totally suppressed, given that only few individuals were recorded in the treated substrate, nine weeks after treatment. Similarly, progeny production of *S. oryzae* was also notably reduced. In contrast, progeny of *R. dominica* was decreased only two times in comparison with progeny production in the control grain. At a concentration of 2 g/kg, after exposure of 4 weeks to DE, 37% of the larvae of *T. castaneum* have emerged to the adult stage, compared with 95% in the control. Nine weeks after treatment, no F1 adults were found in the treated substrate. Similar results were also recorded in the case of 4 g/kg of grain. Twenty individuals of each tested species were separately inserted into each glass jar of 1 L capacity, filled with 500 g of wheat grain. The data is average from three replicates.

4. Discussion

The results of the current experiment indicate that DE concentration, insect species (external or internal feeder), developmental stage and exposure time to the treated commodity influenced the efficacy of tested DE. Among adults, *S. oryzae* and *O. surinamensis* were found to be the most susceptible to DE, regardless of the dose rate. After two and three weeks of exposure to DE, even at the lowest concentration of 0.5 g/kg, mortality of *S. oryzae* was 82 and 92%, respectively. In contrast, *T. castaneum* adults were much more tolerant to DE, given that, at 0.5 g/kg, mortality of *T. castaneum* did not exceed 3%. At the same concentration, mortality of *R. dominica* reached 37%, which was considerably lower than that for *S. oryzae* or *O. surinamensis.* For *T. castansum* and *R. dominica* mortality was high only in the case of the highest dose rate tested (4 g/kg). Hence, longer exposures and dose rates are needed for the control of these species at the adult stage. Our findings are consistent with results obtained by other researches (Korunic, 1998; Fields and Korunic, 2000; Arthur, 2001; 2002; Vayias and Athanassiou, 2004, Arnaud et al., 2005; Athanassiou et al., 2007). Based on the available literature, *Tribolium* spp. are considered the most tolerant to DEs stored-grain beetle species, at the adult stage (Fields and Korunic, 2000; Vayias and Athanassiou, 2004). However, larvae of *T. castaneum,* were very susceptible to DE. Even in cases where larvae survived and reached the adult stage, no progeny was produced. Therefore, it is expected that, despite the fact that adults are tolerant to DEs, susceptibility of larvae may slowly control *T. castaneum* populations. For the confused flour beetle, *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae), Vayias and Athanassiou (2004) also indicated that DE was much more effective against larvae than against adults. From the internal feeders, *S. oryzae* was by far more susceptible than *R. dominica*. This could be attributed to the fact that *R. dominica* adults were more slow-acting, which may reduces the overall contact with the DE particles (Fields and Korunic, 2000). It is known, that, in general, mobile species, such as the rusty grain beetle, *Cryptolestes ferrugineus* (Stephens) (Coleoptera: Cucujidae), are more susceptible to DE than less mobile species (Rigaux et al., 2001; Vardeman et al., 2007). The current results confirm the findings from previous studies, about the rank of stored-product insect species according to their susceptibility to DEs (Korunic, 1998, Fields and Korunic, 2000, Subramanyam and Roesli, 2000; Athanassiou et al., 2004; Vayias and Athanassiou, 2004; Athanassiou and Kavallieratos, 2005; Kavallieratos et al., 2005).

In conclusion, the findings of this work indicate that DE is effective against stored-grain pests, at the dose rate of 1 g/kg or higher. A longer exposure may alleviate the need for increased doses in order to control species that are less susceptible to DEs. It is well established that DE does not react much with the environment, which makes DEs ideal candidates for long-term protection (Korunic, 1998; Subramanyam and Roesli, 2000; Vayias et al., 2006).

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