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Efficacy of Iranian diatomaceous earth deposits against *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae)

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ABSTRACT

Laboratory bioassays were carried out to evaluate the insecticidal efficacy of two Iranian deposits of diatomaceous earths (DEs) and a commercial formulation, SilicoSec®, against adult confused flour beetle (*Tribolium confusum* Jacquelin du Val). The Iranian DEs were dried and sieved to get particle sizes of 0–149, 74–149, 0–74 μm, and 0–37 μm. First, DE samples were applied at the four concentration levels of 500, 1000, 1500 and 2000 ppm and each concentration was replicated four times. Tests were carried out at 27 ± 1 °C and 55 ± 5% r.h. in continuous darkness. The beetle mortality was counted at 2, 7, and 14 days after exposure. Moreover, another experiment was conducted to estimate the LC_{50} values of the DEs. For the first experiment, adult beetle mortality exceeded 51% when exposed for 2 d to 2000 ppm of SilicoSec®. Complete mortality was recorded at each concentration of SilicoSec® at an exposure longer than 7 days except for 500 ppm; while mortalities of *T. confusum* at 2000 ppm of Maragheh and Mamaghan samples with the 0–149 μm particle size were 40.62% and 85.41%, respectively. Mortality of *T. confusum* was influenced by concentration and time of exposure to the DEs. SilicoSec® was the most effective DE followed by Mamaghan samples. The Maragheh samples were the least effective. In addition, in most cases fractions with smaller particles were more effective than larger ones. More experiments are necessary to process natural DEs and make them commercially exploitable.

Introduction

Alternative methods are being emphasized to reduce the use of insecticides to reduce human exposure and to decrease the development of insecticide resistance. Diatomaceous earths (DEs) are among the most promising alternatives to chemical insecticides and fumigants, because they have low mammalian toxicity, do not break down rapidly, and do not affect grain end-use quality (Korunic et al., 1996). DEs absorb the wax layer of insect's cuticle causing death due to desiccation and to a lesser degree by abrasion (Ebeling, 1971; Quarles, 1992). The efficacy of DEs depends on different properties such as particle size distribution, diatom shape, pH value, SiO_2 content, and oil adsorption capacity (Korunic, 1997). To make DEs exploitable for commercial use, they need to be processed by quarrying, drying and milling (Korunic, 1998).

The confused flour beetle, *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae) is one of the most injurious pests of flourmill and cause damage to commercial grain products. This species is probably one of the least susceptible stored-product pests to DE. Therefore, a DE formulation able to control this species could be able to control most insect pests that occur in storage (White and Loschiavo, 1989; Fields and Korunic, 2000; Athanassiou et al., 2005).

Korunic (1997) investigated the efficacy of several DE deposits collected from different countries against *Sitophilus oryzae* (L.) and *Tribolium castaneum* (Herbst). The author suggested accessing the insecticidal activity of DEs by determining their properties without conducting bioassays. The insecticidal activity of DE deposits obtained from southeastern Europe was influenced by the particle size (Vayias et al., 2009b).

The cost of importing pesticides and DEs to Iran is high. Therefore, applying natural native substances decreases the cost of pest management. Northwest Iran has natural mines of DE. Nevertheless, only two of these mines (Maragheh and Mamaghan region) is quarried and processed for purification of water, filtration of commercial fluids, clarification, and other industrial uses. However, the insecticidal activity of these DE deposits has not been studied until now.

The aim of the current study was (I) to evaluate the insecticidal activity of two Iranian deposits and SilicoSec® formulation of DE against *T. confusum*, (II) to evaluate the effect of particle size on the insecticidal activity of each fraction, and (III) to measure physical properties of the DEs and chemical composition of Iranian deposits.

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Table 1
Particle size distribution proportions of Iranian diatomaceous earth deposits.

DE samples	0–149 μm (% w/w)	74–149 μm (% w/w)	< 74 μm (% w/w)	< 37 μm (% w/w)	
				From < 74 μm	From total
Maragheh	100.0	9.75	90.25	36.10	32.58
Mamaghan	100.0	9.32	90.68	63.70	57.84

Table 2
Chemical component percentages of Iranian diatomaceous earth deposits.

Chemical component	Maragheh	Mamaghan
LOI[a]	7.510	6.460
Na_2O	0.730	0.445
MgO	0.757	0.271
Al_2O_3	7.721	1.139
SiO_2	75.346	89.869
Cl	0.00	0.235
P_2O_5	1.103	0.000
SO_3	0.045	0.099
K_2O	1.258	0.198
CaO	2.782	0.371
TiO_2	0.250	0.060
MnO	0.128	0.000
Fe_2O_3	2.338	0.853
Sr	0.023	0.000
Zr	0.009	0.000

[a] Loss on ignition.

Materials and methods

Insects and commodity

Adults of *T. confusum* used in the experiments were obtained from cultures that had been maintained in the Entomology laboratory of Tarbiat Modares University for at least 3 years, without no history of exposure to insecticides. Beetles were reared on wheat flour plus 5% brewer yeast (by weight) at 27 ± 1 °C and 65 ± 5% r.h. in continuous darkness. All adults used in the experiments were 7–14 days old and of mixed sex.

Wheat (variety Pishtaz Madary) was purchased from Agricultural Support Services Company used for the experimentations. Wheat kernels were stored at −24 °C, for at least 48 h. Before the experiments started, wheat kernels were kept for a week in incubators set at 27 ± 1 °C and at 55 ± 5% r.h. to achieve the moisture content related to environmental relative humidity. The moisture content (m.c.) of wheat was measured by milling then drying 10 g of wheat in a ventilated oven set at 110 °C. The m.c. ranged about 12% which is equilibrium to 55% r.h. (Pixton and Warburton, 1971). Fifty grams of wheat (whole plus cracked wheat with the ratio of 9:1) were used for each treatment. Cracked wheat was included both to represent real practice and to make sure the food was accessible for *T. confusum* adults.

DE deposits

Two Iranian deposits of DE were used in the bioassays obtained from mines in northwest Iran from marine origins. One of the deposits was collected from a mine in Mamaghan region (37°50′18″N 46°2′25″E) and the second from Maragheh region (37°22′41″N 46°19′28″E). In addition, the efficacy of SilicoSec®, a commercial DE formulation, was evaluated for comparative purposes. SilicoSec® is a freshwater formulation composed of 92% SiO_2, 3% Al_2O_3, 1% Fe_2O_3, and 1% Na_2O (Biofa GmbH, Münsingen, Germany). The median particle size of SilicoSec® is between 8 and 12 μm (EGMSDS, 2003).

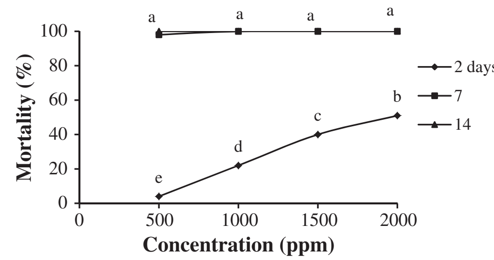

Fig. 1. Mean mortality (%) ± SE of *T. confusum* adults exposed to different concentrations of SilicoSec® formulation at 2, 7 and 14 days after exposure. Means followed by the same letter are not significantly different (Tukey's test, $P = 0.05$).

DE preparation

The method of preparing Iranian deposits was similar to that of Korunic (1997) and Vayias et al. (2009b). Iranian DEs were milled and then dried in an oven set at 60 °C for 24 h to achieve about 3–6% moisture content. Subsequently, samples were sifted using lab sieve with opening of 149 μm (100 mesh) to remove all particles larger than 150 μm. These particles, generally speaking, contain very little clay, sand, or other impurities. The second step was to take a larger part of sample containing particles < 149 μm and sieve them using sieve with opening of 74 μm (200 mesh). At the end, another part of the samples with less than 74 μm particle sizes were sifted with 400 mesh sieve to obtain particles < 37 μm. So, four fractions a) with particle sizes of 0–149 μm, b) 74–149 μm c) < 74 μm and d) < 37 μm were prepared for the bioassays. The proportion of particle size distribution in each fraction to the base of DE was determined by measuring the weight of each fraction (Table 1).

Measurement of DEs physical and chemical properties

DEs properties were determined as described by Korunic (1997) and the measurement of properties was repeated four times (except for chemical component).

Fractions with < 37 μm sized-particles were used for determining of Iranian DEs properties.

Chemical component

Chemical component of Iranian deposits was determined using X-ray florescence analysis in the Geology XRF laboratory, Tarbiat Modares University.

Value of pH

To assess the pH value, 2 g of each DE was stirred to 18 mL double distilled water and the pH value was measured with CONSORT pH Metre Model C835.

Tapped density

To assess DEs tapped density, 10 g of each DE was poured into a 100 mL graduated cylinder with a rubber that covers the bottom of

Table 3
Physical and chemical properties of SilicoSec®, Maragheh and Mamaghan samples of diatomaceous earth (DE).

DEs	pH value	Bulk density reduction (kg/hL)	DE Tapped density (g/L)	Adherence of DEs to wheat kernels (%)	SiO_2 content (%)
SilicoSec®	5.63 ± 0.16 (+)	3.24 ± 0.055 (+)	286.99 ± 1.86 (+)	78.47 ± 0.70 (+)	92.00 (+)
Maragheh	7.28 ± 0.09 (+)	2.63 ± 0.105 (+)	472.02 ± 2.65 (−)	70.40 ± 0.29 (+)	75.35 (−)
Mamaghan	8.07 ± 0.06 (+)	2.817 ± 0.04 (+)	515.63 ± 6.09 (−)	61.27 ± 0.86 (−)	89.87 (+)

(+): Increased DEs insecticidal activity.
(−): Decreased DEs insecticidal activity.