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Article

Efficacy of diatomaceous earth and sulfur on some mites (Acari) under laboratory and semi-field conditions

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ABSTRACT

Laboratory tests and semi-field evaluation were carried out to examine the acaricidal effect of four concentrations of diatomaceous earth (DE) and sulfur against four mites: *Tetranychus urticae* (Tetranychidae), *Rhizoglyphus echinopus* (Acaridae), *Tyrophagus putrescentiae* (Schrank) (Acaridae), and *Amblyseius swirskii* (Phytoseiidae). Results revealed that mortality increased as both time and concentration increased. *Tetranychus urticae* was the most affected mite; LC₅₀ values were 70.4 and 92.0 for immature and adult stages, respectively, after 7 days. For the LC₅₀ concentrations examined, a significant decrease in the total number of immature and adult stages of all mites during seven days was noticed. Under semi-field conditions, the LC₅₀s were calculated for (DE) and sulfur against *T. urticae* on cucumber plants. The reduction percentage of *T. urticae* was 66.67 and 50% for (DE) and sulfur, respectively, after seven days of application, with significant differences.

KEYWORDS: *Amblyseius swirskii*, *Rhizoglyphus echinopus*, *Tetranychus urticae*, toxicity, *Tyrophagus putrescentiae*.

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INTRODUCTION

The host range of *Tetranychus urticae* Koch is extensive. It includes a variety of crops grown in glasshouses, including flowers like orchids and chrysanthemums as well as vegetables like tomatoes, cucumbers, and peppers. Strawberries, both protected and unprotected, are also affected. It poses an issue for grapevines and field-grown fruit crops like apples and pears in certain regions. Cotton, soybeans, and other important legume crops are also infested. A source of infestation may come from this mite's ability to survive on a variety of non-crop hosts. A more exhaustive list of hosts is provided (Bolland *et al.* 1998).

The storage mite *Tyrophagus putrescentiae* (Schrank) (Acari: Acaridae) is one of the most important pests in stored foods (cheese, corn, oats, wheat, soy, etc.), and it is found in heavy infestations (Duek *et al.* 2001). This species is also capable of colonizing homes, dust in urban settings, food factories, medical and laboratory facilities, and farms (Franz *et al.* 1997; Solarz *et al.* 2007).

The two most significant species in this genus, *Rhizoglyphus echinopus* (Fumouze & Robin, 1868) and *R. robini* Claparède, 1869, are known to harm a range of crops, including greenhouses and

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fields; these include ornamentals (lilies and other flower bulbs) and vegetables (onions, garlic, and other veggies) (Diaz *et al.* 2000). *Amblyseius swirskii* Athias-Henriot has been observed to feed and procreate on a broad variety of prey from several orders, such as plant feeding mites (spider, broad, and eriophyoid), whiteflies (greenhouse and silver leaf), and thrips (western flower, onion, melon, and chili) (Nomikou *et al.* 2001; Wimmer *et al.* 2008; Stansly and Castillo 2010; Calvo *et al.* 2011; Dođramaci *et al.* 2011; Onzo *et al.* 2012; Xiao *et al.* 2012; Elhalawany *et al.* 2024).

Diatomaceous earth (DE), a naturally occurring substance made from fossilized diatoms, is one natural product that is being used more and more for pest control. DE dust has several uses, such as filter aid, mineral filler, and invertebrate control agent. It is primarily made up of amorphous silica (Collins and Cook 2006).

Diatomaceous earth is a natural, organic pesticide that can be used to kill spider mites. It is made up of many tiny fossilized diatoms, which are tiny, sharp-edged particles that lacerate the bodies of spider mites and other insects, leading to death. Diatomaceous earth is lethal to spider mites and works by dehydrating the exoskeletons of the mites and killing them. It is also deadly for several other insects, although it will not harm humans or pets.

To use diatomaceous earth for spider mites, you can spread it on the soil or mix it with water to create a spray. DEs operate in a physical manner. When pests walk over a surface that has been treated, they pick up dust, which damages the cuticle through abrasion and sorption of cuticulin waxes. This causes the body to lose water, which causes desiccation and death (Ebeling 1971).

Therefore, this study's objective was to evaluate the efficacy of the diatomaceous earth (DE) and sulfur in controlling *T. urticae*, *R. echinopus*, *Tyrophagus putrescentiae* and *Amblyseius swirskii* under laboratory conditions, as well as evaluate the DE and sulfur in semi-field conditions on *T. urticae* infested cucumber plants.

MATERIALS AND METHODS

Culture of Tetranychus urticae

The stock colony of *T. urticae* was collected from infested cucumber plants (*Cucumis sativus* L.). They were reared in a plastic tray (23 × 20 × 70 cm). Adult mites were moved to a clean castor bean leaf, lower side up, and set on cotton pads that had been moistened and were sitting on sponges in the foam dish (15 × 20 cm). The colonies were kept in a laboratory setting at room temperature. Water was added when needed. Mites were housed in a laboratory at 25 °C with appropriate moisture levels at 70% RH. The same environmental conditions were used for the cultures used for all bioassays (Mahmoud 2016).

Rearing of Tyrophagus putrescentiae and Rhizoglyphus echinopus

The astigmatid mites, *T. putrescentiae* and *Rhizoglyphus echinopus* were collected from the fallen date palm fruits (at the orchard of Research Station of the Agricultural Research Center, Giza Governorate, Egypt) using a Berlese funnel at Acarology laboratory in Plant Protection Research Institute, A.R.C., Dokki. For preparing pure cultures of the tested mites, plastic cups (1.5 cm high × 2.5 cm diameter) were filled up to 0.5 cm with substrate (plaster of paris and activated charcoal in the rate of 8: 2, respectively). One adult female and male of *T. putrescentiae* were supplied with semi dry date fruits as food and drops of water (to maintain suitable relative humidity) and incubated at 25 °C. For individual rearing, 10 newly deposited eggs of mite were transferred from the mother culture to rearing plastic cells. Each newly hatched larva was supplied with food and kept till reaching maturity. Mites were examined twice a day (Abdel-Khalik 2018)

Source of Amblyseius swirskii

The colony of *A. swirskii* was established from mites obtained from Qaha Station, Plant Protection Research Institute, Qalubia Governorate 2023. Predator mite *A. swirskii* was cultured and

kept in the laboratory at 25 ± 2 °C and 70% RH with a photoperiod of 16: 8 (L: H) using *Carpoglyphus lactis* (L.) (Carpoglyphidae) and *Tyrophagus putrescentiae* (Schrank) (Acaridae) as food sources according to Elhalawany *et al.* (2023).

Source of diatomaceous earths (DE)

A pure natural DE containing 80% SiO₂ with grain size of 74 micrometers was used. This product is manufactured in Tekkim company which has been certified to conform to ISO 9001 20 2015 standard of Quality Management system.

Source of sulfur

This product (Agricultural sulfur) is manufactured in Kafr El Zayat pesticides and Chemicals company super fine granules.

Experimental design

Tetranychus urticae

A castor bean leaf disc (5 cm in diameter) was flipped over and placed on wet cotton pads sitting on a sponge in an experimental foam dish (15 × 20 cm). In order to keep the culture healthy and stop the individuals of *T. urticae* from escaping, water was introduced when needed. Four treatments and a control were applied, totally 50 experimental foam dishes, with 10 duplicates for each treatment.

Laboratory experiment

Twenty adult females of *T. urticae* were placed on the lower surface of a newly castor bean leaf disc. Four concentrations (25, 50, 75, and 100%) in each treatment DE and sulfur and 10 replicates of each concentration were given a prior treatment with a fine camel hairbrush. One of the earlier treatments was applied to the leaf discs with 2 gm. Talcum powder was used as a control in each test. Mortality was calculated using a binocular microscope at 3, 5, and 7 days post treatments and corrected using Abbott's method (1925), and Finney's (1971) estimates of the LC₅₀, LC₉₀, and slope values were used. The castor bean discs were maintained at room temperature (25 ± 2 °C, $70 \pm 5\%$ RH). A mite was considered dead when its body or appendages did not move when it was probed with a fine camel brush (Elhalawany and Dewidar 2017; Elhalawany *et al.* 2019)

Tyrophagus putrescentiae and Rhizoglyphus echinopus

To assess the efficacy of DE and sulfur on *T. putrescentiae*, and *R. echinopus*. They were treated with four doses of DE and sulfur (25, 50, 75, and 100 %). Each set was replicated 10 times. The LC₅₀ values the LC₅₀ values were evaluated for adult and immature stages 7 days after treatment. Mortality was calculated using a binocular microscope at 3, 5, and 7 days post-treatments and corrected using Abbott's method (1925), and Finney's (1971) estimates of the LC₅₀, LC₉₀, and slope values were used.

Amblyseius swirskii

To evaluate the efficacy of DE and sulfur on *Amblyseius swirskii*, Leaf discs of castor bean were used as a rearing substrate infected with *T. urticae*. DE and sulfur were used in four concentrations (25, 50, 75, and 100%). Control was treated with Talcum powder. The discs were placed in Petri dishes, upper surface downwards, on water-saturated cotton. The Petri dishes were then encircled with a thin layer of wet cotton to confine the individuals. LC₅₀ was evaluated for adult stage 7 days after treatment. Mortality was calculated using a binocular microscope at 3, 5, and 7 days post-treatment and corrected using Abbott's method (1925), and Finney's (1971) estimates of the LC₅₀, LC₉₀, and slope values were used (El-Badry *et al.* 1968).

Semi-field experiment

Cucumber plants were grown in pots under open field at Qaha Station, Plant Protection Research

Institute, Qalubiya governorate. Each pot contained three plants. After two weeks of planting, the plants were infested with 40 adults of *T. urticae* per each pot. After one week of exposure to the LC₅₀s of DE, sulfur and control (dusted with Talcum powder), twenty leaves were chosen randomly from each treatment and the number of motile mite stages was counted before dusting and after 3, 5 and 7 days of application using the aid of a stereomicroscope. Henderson and Tilton's (1955) equation was used to estimate the reduction percentage of the spider mite (immature and adult).

Statistical analysis

Probit analysis (Finney 1971) was applied to the data from each dose-response bioassay in order to determine the LC₅₀ and LC₉₀ values using Ldp line software (Bakr 2005). Reduction percentage of *T. urticae* moving stages was analyzed by one-way ANOVA and means were compared by using LSD test at $\alpha = 0.05$ in SAS Program version 9.1.3 (SAS Institute 2003).

RESULTS

Diatomaceous earth (DE) and sulfur offer effective natural products as alternatives for *Tetranychus urticae* control. These dusts simplify handling and application, and they may also be a less expensive option when it comes to chemical control.

Toxicity effect of DE and sulfur dust against *Tetranychus urticae* immature and adult stages after 3, 5, and 7 days

Data showed that the mortality rate of the immature and adult stages of the spider mite treated with DE increased with increasing concentrations at an exposure time of 7 days. LC₅₀ and LC₉₀ were calculated. The LC₅₀ were 55.6 and 165.0 g/m² for immature and 78.5 and 109.5 g/m² for adult after 7 days post-treatment for (DE) and sulfur, respectively. Whereas, the LC₉₀ values were 228.1 and 3817.0 g/m² for immature, and 276.4 and 529.3 g/m² for adult after 7 days post-treatment for (DE) and sulfur, respectively. The four different dust concentrations turned out to be ineffective on immature and adult stages. The slope of the toxicity lines, which resulted from treated adult of *T. urticae* are steeper than those from treated immature stages. This indicates that the immature mites are more sensitive than adults to (DE) and sulfur (Tables 1, 2).

Table 1. Toxicity effect of DE and sulfur dust against *Tetranychus urticae* immature stages after 3, 5, and 7 days.

Treatments	Time (day)	LC ₅₀ (g/m ²)	Confidence limits of LC ₅₀		Slope	Toxicity index	χ^2
			Lower	Upper			
DE	3	70.4a	56.0	98.7	1.3	79.0	1.3
	5	70.5a	58.9	89.8	1.6	78.9	1.3
	7	55.6a	48.0	64.4	2.1	100.0	1.0
Sulfur	3	233.5b	130.0	2367.4	1.0	23.8	4.2
	5	201.6b	127.5	742.5	1.2	27.6	3.6
	7	165.0b	102.6	987.2	0.9	33.7	3.0

χ^2 = Chi-square, Toxicity index was calculated with respect to the most effective compound LC₅₀.

Means with the same letters within the same column were not significantly different at $p < 0.05$ according to LSD test.

Mean % mortality of predatory mite *Amblyseius swirskii* exposed to four doses of DE and sulfur dust after 3, 5 and 7 days

Test with diatomaceous earth (DE) on adult stages of *Amblyseius swirskii* showed mortality percentages with different concentrations after 7 days post-treatment were significantly different ($F = 68.06$, $df = 7$, $P < 0.0001$). The mean mortality percentage was 50.07% at the highest concentration

(DE) 100% followed by 37.97% mortality for sulfur (Dose g/m²) (Table 1). This means that the adults of *A. swirskii* were a little affected by the higher concentrations of (DE) and sulfur.

Table 2. Toxicity effect of DE and sulfur dust against *Tetranychus urticae* adult stages after 3, 5, and 7 days.

Treatments	Time (day)	LC ₅₀ (g/m ²)	Confidence limits of LC ₅₀		Slope	Toxicity index	χ ²
			Lower	Upper			
DE	3	92.0	74.4	133.1	1.5	85.3	1.2
	5	207.0	129.2	815.6	1.2	37.9	2.6
	7	78.5	68.7	93.5	2.3	100.0	1.0
Sulfur	3	147.0	110.0	267.6	1.7	53.4	1.9
	5	125.7	98.6	199.2	1.8	62.5	1.6
	7	109.5	88.9	157.4	1.9	71.7	1.4

χ² = Chi-square, Toxicity index was calculated with respect to the most effective compound LC₅₀.

Table 3. Mean ± SD mortality percentage of predatory mite *Amblyseius swirskii* exposed to four doses of DE and sulfur dust after 3, 5, and 7 days.

Treatments	Dose (%)	Means ± SD		
		3 days	5 days	7 days
DE	25%	19.84 ± 2.12e	31.85 ± 1.48d	9.69 ± 2.04e
	50%	22.18 ± 2.16d	37.91 ± 1.52c	31.54 ± 2.08c
	75%	30.77 ± 2.01b	43.59 ± 1.41b	45.64 ± 1.93a
	100%	40.50 ± 1.89a	54.63 ± 1.32a	50.07 ± 1.81a
Sulfur	25%	23.89 ± 1.84cd	27.95 ± 2.36ef	19.68 ± 2.03d
	50%	24.37 ± 1.81c	25.05 ± 2.32f	20.07 ± 2.00d
	75%	25.58 ± 1.97c	31.02 ± 2.51de	18.88 ± 2.17d
	100%	32.35 ± 1.76b	36.47 ± 2.25c	37.97 ± 1.94b

Means ± SD have the same letters within the same column been not significantly different at p < 0.05 according to LSD test

Toxicity effect of diatomaceous earth dust against Rhizoglyphus echinopus and Tyrophagus putrescentiae immature and adult stages after 3, 5, and 7 days

Probit analysis for DE dust efficacy against *R. echinopus* and *T. putrescentiae* immature and adults after 3 to 7 days are presented in Tables 4 and 5. Mortality increased as both time and concentration increase. Immature stages were more affected than adults. The corresponding LC₅₀ values after seven days were 48.4 and 62.8 and the LC₉₀ values were respectively 190.3 and 214.3 g/m² for *R. echinopus* and *T. putrescentiae* immature, respectively. The slope values of regression line were respectively 2.2 and 2.4 for *R. echinopus* and *T. putrescentiae* immature after seven days, with relative toxicity (100: 77.1) Table 4. These results showed that immature stages of *R. echinopus* are more sensitive than *T. putrescentiae* immature ones.

Data in Table 5 proved that the mortality rate of adult stages of the astigmatid mites treated with DE increased with increasing concentrations and exposure time. The LC₅₀ were 82.4 and 70.5 g/m² for *R. echinopus* and *T. putrescentiae* adult after 7 days post-treatment for (DE), respectively. Whereas, the LC₉₀ values were 576.5 and 240.4 g/m² for *R. echinopus* and *T. putrescentiae* adults, respectively.

Table 4. Toxicity effect of DE against *Tyrophagus putrescentiae* and *Rhizoglyphus echinopus* immature stages after 3, 5, and 7 days.

Treatments	Time (day)	LC ₅₀ (g/m ²)	Confidence limits of LC ₅₀		Slope	Toxicity index	χ^2	LC ₉₀
			Lower	Upper				
<i>R. echinopus</i>	3	105.7a	91.0	133.1	2.7	45.9	2.2	315.5
	5	88.7a	72.5	123.6	1.6	54.7	1.8	559.3
	7	48.5b	41.4	55.6	2.2	100.0	1.0	190.3
<i>T. putrescentiae</i>	3	118.5a	99.3	158.9	2.6	40.9	2.4	375.6
	5	111.7a	89.6	166.2	1.8	43.4	2.3	586.9
	7	62.9b	55.5	72.0	2.4	77.1	1.3	214.3

χ^2 = Chi-square, toxicity index was calculated with respect to the most effective compound LC₅₀.

Means have the same letters within the same column been not significantly different at $p < 0.05$ according to LSD test.

Table 5. Toxicity effect of DE against *Rhizoglyphus echinopus* and *Tyrophagus putrescentiae* adult stages after 3, 5, and 7 days.

Treatments	Time (day)	LC ₅₀ (g/m ²)	Confidence limits of LC ₅₀		Slope	Toxicity index	χ^2
			Lower	Upper			
<i>R. echinopus</i>	3	125.9a	104.1	174.2	2.6	56.0	1.8
	5	124.4a	94.7	218.8	1.5	56.6	1.8
	7	82.4b	67.4	114.0	1.5	85.5	1.2
<i>T. putrescentiae</i>	3	131.7a	108.9	183.6	2.8	53.5	1.9
	5	143.0a	107.6	256.2	1.7	49.3	2.0
	7	70.5b	62.2	81.9	2.4	100.0	1.0

χ^2 = Chi-square, toxicity index was calculated with respect to the most effective compound LC₅₀.

Means have the same letters within the same column been not significantly different at $p < 0.05$ according to HSD test.

Data (Tables 6, 7) shows that the mortality rate of immature and adult stages of the astigmatid mites treated with DE increased with increasing concentrations and exposure time. The LC₅₀ values were 89.1 and 65.0 g/m² for *R. echinopus* and *T. putrescentiae* immature after 7 days post-treatment for (DE), respectively. Whereas, the LC₅₀ values were 89.1 and 117.2 g/m² for *R. echinopus* and *T. putrescentiae* adult, respectively. These results showed that immature stages of *R. echinopus* and *T. putrescentiae* more sensitive than adult stages.

Table 6. Toxicity effect of DE against *Rhizoglyphus echinopus* and *Tyrophagus putrescentiae* immature stages after 3, 5 and 7 days.

Treatments	Time (day)	LC ₅₀ (g/m ²)	Confidence limits of LC ₅₀		Slope	Toxicity index	χ^2
			Lower	Upper			
<i>R. echinopus</i>	3	124.7a	102.8	173.5	2.5	52.1	1.9
	5	108.6b	84.6	177.5	1.5	59.9	1.7
	7	89.1b	69.3	145.3	1.2	73.0	1.4
<i>T. putrescentiae</i>	3	131.7a	108.0	186.4	2.6	49.4	2.0
	5	144.1a	102.0	334.8	1.3	45.1	2.2
	7	65.0b	50.1	92.8	1.1	100.0	1.0

χ^2 = Chi-square, Toxicity index was calculated with respect to the most effective compound LC₅₀.

Means have the same letters within the same column been not significantly different at $p < 0.05$ according to LSD test.

Table 7. Toxicity effect of sulfur dust against *Rhizoglyphus echinopus* and *Tyrophagus putrescentiae* adult stages after 3, 5 and 7 days.

Treatments	Time (day)	LC ₅₀ (g/m ²)	Confidence limits of LC ₅₀		Slope	Toxicity index	χ^2
			Lower	Upper			
<i>R. echinopus</i>	3	163.0b	122.9	288.2	2.1	54.7	1.8
	5	124.4b	94.7	218.8	1.5	71.6	1.4
	7	89.1b	72.4	126.5	1.5	100.0	1.0
<i>T. putrescentiae</i>	3	203.0a	140.9	468.9	1.9	43.9	2.3
	5	144.3b	107.5	268.1	1.6	61.7	1.6
	7	117.2b	89.8	201.8	1.5	76.0	1.3

χ^2 = Chi-square, Toxicity index was calculated with respect to the most effective compound LC₅₀.

Means have the same letters within the same column been not significantly different at $p < 0.05$ according to LSD test.

Semi-field experiment

The three doses of 50, 75, and 100% g/m² of DE and sulfur was dust on cucumber plants under semi-field conditions, and the control was dust with Talcum powder. The data (Tables 8, 9) shows that there was a significant difference between DE and sulfur in number before application. Results indicated that the motile stages of *T. urticae* on cucumber leaves after dust decreased gradually till the end of the test. The reduction percentage of *T. urticae* individuals was 53.33, 62.96, and 66.67% for DE (100 %), and it was 40.0, 51.8, and 50.0% for sulfur after 3, 5 and 7 days post-treatment, respectively.

Table 8. Effect of three doses of DE and sulfur dust against *Tetranychus urticae* on cucumber under semi-field.

Treatments	Dose (%)	Mean \pm SD of <i>T. urticae</i> after		
		3 days	5 days	7 days
DE	50%	7.00 \pm 1.0ab	5.67 \pm 0.6a	4.33 \pm 0.6b
	75%	5.67 \pm 0.6bc	4.00 \pm 1.0b	3.67 \pm 0.6bc
	100%	4.67 \pm 0.6c	3.33 \pm 0.6b	2.67 \pm 1.2c
Sulfur	50%	8.00 \pm 1.0a	6.67 \pm 0.6a	5.67 \pm 0.6a
	75%	7.00 \pm 0.0ab	5.67 \pm 0.6a	4.67 \pm 0.6ab
	100%	6.00 \pm 1.0bc	4.33 \pm 0.6b	4.00 \pm 0.0b

Means \pm SD have the same letters within the same column been not significantly different at $p < 0.05$ according to LSD test.

Table 9. Reduction percentages (mean \pm SD) of *Tetranychus urticae* caused by three doses of DE and sulfur on cucumber under semi-field

Treatments	Dose (%)	Reduction % \pm SD of <i>T. urticae</i> after		
		3 days	5 days	7 days
DE	50%	30.00 \pm 10.0bc	37.04 \pm 6.4b	45.83 \pm 7.2b
	75%	43.33 \pm 5.8 ab	55.56 \pm 11.1a	54.17 \pm 7.2ab
	100%	53.33 \pm 5.8 a	62.96 \pm 6.4a	66.67 \pm 14.4a
Sulfur	50%	20.00 \pm 10.0c	25.93 \pm 6.4b	29.17 \pm 7.2c
	75%	30.00 \pm 0.0 bc	37.04 \pm 6.4b	41.67 \pm 7.2bc
	100%	40.00 \pm 10.0ab	51.85 \pm 6.4a	50.00 \pm 0.0b

Means have the same letters within the same column been not significantly different at $p < 0.05$ according to LSD test

DISCUSSION

Regarding the DE and sulfur, the results in this experiment indicate that mites' mortality was increased

with increasing concentration and period of time after application. These outcomes confirm data from previous studies. Abo Al Hab *et al.* (2023) mentioned that the control of beetles, *Oryzaephilus surinamensis* (L.) with a commercial formulation of the Diatomaceous Earth (silicon dioxide), was more efficient on the 2nd–5th instar larvae and adults of *O. surinamensis*. The results indicated that Diatomaceous Earth (DE) was significantly effective at all tested concentrations after 7 days post-treatment. Kilpinen and Steenberg (2016) found that *Dermanyssus gallinae* (De Geer) was effectively controlled by DEs. Akhtar and Isman (2013) showed that a liquid formulation of DEs produced high rates of poultry red mite population mortality in field bioassays. The application of DE in conjunction with mechanical cleaning resulted in a gradual reduction of the mite population, from 34% on day 7 to 53% on day 14 and over 90% on days 21–28. DE formulations showed minimal danger to the spider mite's predator, in contact bioassays. *Tetranychus urticae* Koch, when DEs were tested in contact bioassay of Shah and Appleby (2019), including *Phytoseiulus persimilis* Athias-Henriot (Phytoseiidae), *Neoseiulus fallacis* Garman (Phytoseiidae), and *Stethorus punctillum* (Weise) (Coccinellidae). Collins *et al.* (2006) found that at equivalent dosages, the dry dust applications outperformed the slurry applications for both DEs. The least tolerant insect species was *Oryzaephilus surinamensis*, followed by *Sitophilus granarius* (L.) and *Tribolium castaneum* (Herbst). *Lepidoglyphus destructor* (Schrank) was more tolerant than *Acarus siro* L., a type of mite. Wakil *et al.* (2010) revealed that at 25 °C and 45% R.H., DE had the highest mortality rate of 61.3%., *Metarhizium anisopliae* gave maximum mortality of mite *Tyrophagus fatimii* Wakil *et al.* (Astigmata: Acaridae), 48.7% at 20 °C and 55% R.H. at 3.6×10^9 conidia/kg of wheat. It was concluded that the efficacy of both DE and *M. anisopliae* increased with the increase in the exposure interval. Moreover, the increase in dose increased mortality. In addition, temperature and R.H. are the key factors for determining the effectiveness of both DE and *M. anisopliae*. Several DE formulations are commercially available and many studies document that they are very effective against a wide range of stored-product insect species. However, the main drawback in the use of DEs is that they need to be applied at high-dose rates, and these affect the physical properties, chiefly bulk density, of the stored grains (Korunic *et al.* 1998).

CONCLUSION

Future pest management plans may benefit greatly from the use of inert dusts, such as DE formulations, which guarantee a plentiful supply of nutritious food. While there is a wealth of information available about their insecticidal and acaricidal qualities, not much progress has been made in terms of determining the best way to process DE dusts for use as pesticides and acaricides. This study demonstrates that DE formulations can be employed in integrated pest management programs and have negligible non-target effects.

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تأثیر خاک دیاتومه و گوگرد بر روی برخی کنه‌ها (Acari) در شرایط آزمایشگاهی و نیمه صحرایی

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چکیده

آزمایش‌های آزمایشگاهی و ارزیابی نیمه‌صحرایی برای بررسی اثر کنه‌کشی چهار غلظت خاک دیاتومه (DE) و گوگرد علیه چهار کنه انجام شد: *Tyrophagus putrescentiae* (Acaridae) *Rhizoglyphus echinopus* (Acaridae) *Tetranychus urticae* (Tetranychidae) و *Tetranychus urticae* (Phytoseiidae) *Amblyseius swirskii* نتایج نشان داد که با افزایش زمان و غلظت، مرگ و میر افزایش یافت. بیشترین آسیب را دید؛ مقادیر LC50 پس از ۷ روز برای مراحل نابالغ و بالغ به ترتیب ۷۰/۴ و ۹۲/۰ بود. برای غلظت‌های LC50 مورد بررسی، کاهش بسیاری در تعداد کل مراحل نابالغ و بالغ همه کنه‌ها در طول هفت روز مشاهده شد. در شرایط نیمه صحرایی، برای LC50s برای خاک دیاتومه و گوگرد علیه *T. urticae* در گیاهان خیار محاسبه شد. درصد کاهش *T. urticae* برای خاک دیاتومه و گوگرد به ترتیب ۶۶/۶۷ و ۵۰ درصد پس از هفت روز از کاربرد با تفاوت معنی‌دار بود.

واژگان کلیدی: *Tyrophagus putrescentiae*، سمیت، *Tetranychus urticae* *Rhizoglyphus echinopus* *Amblyseius swirskii*

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