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The effect of surface type on the insecticidal efficacy of Iranian diatomaceous earth compared with SilicoSec® formulation against adult *Rhyzopertha dominica* and *Tribolium confusum*

F. Zarasvandi[1], A. A. Seraj[2], M. Ziaee[2*]

1. M. Sc. Graduate Student, Department of Plant Protection, Faculty of Agriculture, Shahid Chamran University of Ahvaz, Ahvaz, Iran
2. ***Corresponding Author:** Associate Professor, Department of Plant Protection, Faculty of Agriculture, Shahid Chamran University of Ahvaz, Ahvaz, Iran (m.ziaee@scu.ac.ir)

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Abstract

Considering the adverse effects of storage insect pests and their resistance to chemical insecticides, identifying safe, cost-effective, and durable methods to control and reduce storage pest-induced damage appears essential. Utilizing diatomaceous earth is one alternative to chemical pesticides for controlling stored-product insect pests. This study evaluated the insecticidal activity of diatomaceous earth at a concentration of 0.2 mg/cm^2 against two stored-products insect pests, *Rhyzopertha dominica* F. and *Tribolium confusum* Jacqulin Duval, on concrete, mosaic, and galvanized steel surfaces. To this end, the surfaces were treated with different diatomaceous earth formulations, including a commercial formulation, SilicoSec®, an Iranian formulation, Dryasil, Dryasil + 0.05% *Mentha longifolia* L. extract, and talcum powder + 0.05% *M. longifolia* extract. Mortality was measured 1, 3, 5, and 7 days after treatment. The experiment was conducted at 27 ± 1 °C, 60 ± 5% relative humidity, and dark conditions. The experiments were performed in nine replications (10 adults in each replication). The mortality percentage of *R. dominica* 7 days after treatment with Silicosec®, Dryasil alone, Dryasil + 0.05% *M. longifolia* extract, and talcum powder + 0.05% *M. longifolia* extract on galvanized steel were 43.33, 54.44, 33.33, and 25.55%, respectively. The results indicated that the mortality percentage of *T. confusum* on galvanized steel was 35.55, 45.55, 26.66, and 23.33%, respectively. The mortality of *T. confusum* was lower than that of *R. dominica* adults. Results indicated that the insecticidal effect of diatomaceous earth increased over time. Diatomaceous earth alone had a more significant insecticidal effect than combining them with *M. longifolia* extract. The highest percentage of mortality in all treatments was found on the galvanized steel, mosaic, followed by concrete surfaces, respectively. Therefore, Dryasil formulation can be used to control stored-products pests in grain silos, although its insecticidal efficacy varies based on surface type.

Keywords: Stored products Pests, concrete, diatomaceous earth, mosaic, galvanized steel

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Introduction

The lesser grain borer, *Rhyzopertha dominica* F. (Coleoptera: Bostrichidae), is regarded as one of the most significant stored cereal insect pests, where severe contamination by this pest causes an unpleasant odor in grains. *R. dominica* attacks stored products, reducing their quality and quantity (Rees, 2007). The confused flour beetle, *Tribolium confusum* Jacqulin Duval (Coleoptera: Tenebrionidae), is also considered one of the most important storage product pests. The damage caused by this insect to storage product typically occurs in the larval, primarily affecting flour and broken grains of cereals. In addition, these pests cause greater damage to grains with high moisture content, resulting in a change in appearance and an unpleasant odor (Hill, 2002).

Diatomaceous earth formed from the fossil remains of single-celled algae called diatoms. Diatoms are found abundantly in aquatic ecosystems and are also seen in dry environments. These algae belong to the geological Eocene and Miocene periods. Diatoms take the required silicon from water to form their silicon skeleton (Losic & Korunic, 2018). There are more than 25,000 species of diatoms, none of which have the same shell and skeleton, but all of them are made of silicon dioxide (Shah & Khan, 2014). After the death of diatoms, their skeletons settle in the water and turn into fossils over many centuries, then they are compressed and change into soft rock. Then, diatomaceous earth is created during processes of drying, milling, etc. (Korunic & Ormesher, 1998). Diatomaceous earth particles contain tiny pores that can absorb insect epicuticle wax molecules. Therefore, when insects come into contact with the cuticle, they absorb the waxy layer of insects' cuticle, cause scratches on the surface of the cuticle, loss of body water and lead to death of insects (Korunić, 2016). The method of dusting and spraying diatomaceous earth is usually applied in empty warehouses, silos, and vehicles used to transport grains to warehouses, after taking sanitary measures to prevent pests from entering warehouses (Korunic, 1997).

The effectiveness of a diatomaceous earth formulation (DiaFil® 610) against *Tribolium castaneum* adults at 0, 2.5, and 5.0 g/m^2 at five temperatures, including 28, 36, 42, 44, and 46 °C on a concrete surface, was evaluated. Temperature increases mortality, where the combination of DE and temperature can be used to control insects in the empty bin (Frederick and Subramanyam, 2016). The effectiveness of the wettable powder formulation of diatomaceous earth (Detech®) against *Sitophilus oryzae* adults on concrete and wooden surfaces was evaluated at 0.25, 0.5, 1, and 2 g/m^2. The adult mortality rate increased as the application rate and duration of exposure increased. Mortality was reported to be greater on concrete surfaces than on wooden surfaces (Ertürk et al., 2020). The insecticidal activity of Iranian diatomaceous earth formulated from Mamaghan Mine, Iran, was compared to two commercial formulations, including SilicoSec®, and Protect-It®, on concrete, galvanized steel, and mosaic against adults of *R.* dominica and T. *confusum*. The formulations exhibited greater persistence and activity on galvanized steel than on concrete and mosaic surfaces. Furthermore, the toxicity of SilicoSec® was greater than that of the other two formulations tested; however, the insecticidal activity of the Protect-It® formulation and Iranian diatomaceous earth was comparable, indicating the high insecticidal potential of Iranian diatomaceous earth (Delgarm & Ziaee, 2021).

Iran has large mines of diatomaceous earth that can protect empty warehouses and silos, stored grain facilities, and grain handling machinery (Delgarm & Ziaee, 2021). Considering the benefits of using diatomaceous earth in controlling stored-product insect pests and access to native resources in Iran, it seems necessary to investigate the performance of Iranian diatomaceous earth deposits. Therefore, this study aimed to investigate the insecticidal activity of Iranian diatomaceous earth alone and in combination with *M. longifolia* extract compared to the commercial formulation on the *R. dominica* and *T. confusum* adults on different surfaces, including concrete, mosaic, and galvanized steel.

Material and methods

Collecting and rearing insects

The colony of *R. dominica* and the *T. confusum* was obtained from the Toxicology Laboratory, Faculty of Agriculture, Shahid

Chamran University of Ahvaz in May 2022. Rearing of *R. dominica* was conducted on wheat (Chamran variety), and rearing of *T. confusum* was carried out on a nutrient medium consisting of 95% wheat flour and 5% yeast. Insects were reared at 27 ± 1 °C, 65 ± 5% relative humidity (r.h.), and continuous darkness. After three generations of rearing, the insects were used to conduct the experiments. In all experiments, 7-14-day old adults were used (Delgarm & Ziaee, 2021).

Diatomaceous earth

Silicosec®, a commercial formulation, was used in this research. Silicosec® formulation is of freshwater origin and consisting of 92% SiO_2, 3% Al_2O3, 1% Fe_2O_3, and 1% Na_2O (Biofa GmbH, Münsingen, Germany). Dryasil, an Iranian formulation consisting of 90% Iranian freshwater diatomaceous earth (containing 92.59% SiO_2, 1.41% Fe_2O_3, 0.88% TiO_2, 0.61% Al_2O3, 0.62% SO_3, and other compounds) + 10% silica aerogel (IGA-NT[1] Co., Ahvaz, Iran). Talcum (Johnson's Co., Canada) containing 100% talcum powder was purchased from a pharmacy. Also, the combination of Iranian formulation Dryasil and *M. longifolia* extract was used.

***Mentha longifolia* extraction**

Mentha longifolia L. was obtained from the foothills of Anhar-e Sofla village, Urmia, West Azerbaijan (37.59187° or 37° 35' 31" north, 44.97551° or 44° 58' 32" east). In order to extract the extraction from the *M. longifolia*, the dried plant sample was first powdered with an electric mill. Extraction was done with methanol solvent (Merck). For this purpose, 10 grams of ground plant tissues were placed in 100 mL of methanol on a shaker for 24 hours at 20 °C, then 75 mL of the solution was removed, and 25 mL of sterile distilled water was added to it. Its volume reached 100 ml. Then the same volume of methanol was added. This mixture was placed on the shaker for two hours; after this, the different parts were separated using a decanter, and the methanolic part was placed under the hood to evaporate the methanol. The extraction was stored in glass containers in a refrigerator until the experiments were conducted (Shazdeahmadi & Sajjadi, 2022).

Insecticidal effect of the Iranian and the commercial diatomaceous earth formulations on different surfaces

The experiment was conducted based on the method of Delgarm & Ziaee (2021) with some modifications in May 2022. In this experiment, diatomaceous earth formulations were added at concentrations of 0.2 mg/cm^2 on different surfaces, including concrete, galvanized steel, and mosaic, which were 30 × 30 cm in size. The treatments were Silicosec®, Iranian formulation Dryasil, Dryasil + 0.05% *Mentha longifolia* L. extract (MLE), talcum powder + 0.05% (MLE). The treatments were spread evenly on the surfaces using a brush, and then the plastic containers with 10 adults were placed upside down to prevent the insects from coming out on the surfaces. Before releasing the insects, 2 grams of wheat (Chamran variety) were placed under the containers for insect feeding. Untreated surfaces were considered as controls. This experiment was performed in nine replications, and 10 adults was released in each replication. Insects that did not move their legs or antennae when stimulated by the needle were considered dead. The experiment was conducted at 27 ± 1 °C, 60 ± 5% r.h. and dark conditions. Mortality was counted 1, 3, 5, and 7 days after treatment.

Data analysis

The normality of the data was checked by the Shapiro-Wilk test. If there were mortality in the control group, the mortality percentage data were corrected by Abbott's formula (Abbott, 1925). The comparison between diatomaceous earth formulations and different surfaces was performed as a factorial design (factor 1: the formulation at four levels; factor 2: the surface at three levels) with a completely randomized design. Statistical analysis was performed using SPSS16 software. The means were separated using Tukey (HSD) test at a 5% significant level (IBM Corp., 2007).

Results

On the first day, no mortality of *R. dominica* adults was recorded on both concrete or mosaic

1- Iranian Green Agriculture New Technology (IGA-NT) surfaces. While Silicosec® and Dryasil treatments on galvanized steel caused 3.33 and 7.77% mortality, respectively, and this mortality percentage in Silicosec® on galvanized steel did not have a significant difference with mosaic and concrete surfaces. However, the adults' mortality percentage of Dryasil treatment on galvanized steel was significantly differed from concrete and mosaic surfaces (Table 1).

On the third day, no *R. dominica* adults' mortality was observed on the concrete surface, except for Dryasil+ MLE. The mortality percentage of adults exposed to the mosaic surface treated with all the treatments was less than 10%. On the galvanized steel surface, the highest mortality level was recorded by Dryasil treatment caused 35.55% mortality followed by Silicosec® (26.66%). While Dryasil + MLE only caused 6.66% mortality of *R. dominica* adults (Table 2).

After five days, *R. dominica* adults' mortality was 15.55% on the concrete surface treated with Silicosec® and Dryasil, which did not have a significant difference. The Dryasil caused 25.55% adult mortality on the mosaic surface, significantly different from other treatments. Also, on galvanized steel, the highest mortality percentage was recorded for Dryasil, which was significantly more than other treatments (Table 3).

Table 1. Mean mortality% ± SE of *Rhyzopertha dominica* on different surfaces treated with different formulations of diatomaceous earth, 1 day after treatment

Treatments	Concrete	Mosaic	Galvanized steel	*P*, $F_{2,24}$
Silicosec®	0.00±0.00B	0.00±0.00B	7.77±1.46aA	<0.001, 28.000
Dryasil	0.00±0.00B	0.00±0.00B	8.88±1.11aA	<0.001, 64.000
Dryasil+ MLE	0.00±0.00	0.00±0.00	0.00±0.00b	-
Talcum + MLE	0.00±0.00	0.00±0.00	0.00±0.00b	-
P, $F_{3,32}$	-	-		<0.001, 27.515

Means with different lowercase letters in each column, and different uppercase letters in each row do not have a significant difference using Tukey HSD test at *P* = 0.05, MLE: *Mentha longifolia* extract.

Table 2. Mean mortality% ± SE of *Rhyzopertha dominica* on different surfaces treated with different formulations of diatomaceous earth, 3 days after treatment

Treatments	Concrete	Mosaic	Galvanized steel	*P*, $F_{2,24}$
Silicosec®	0.00±0.00bC	8.88±1.11aB	26.66±1.66bA	<0.001, 116.857
Dryasil	0.00±0.00bC	6.66±1.66aB	35.55±1.75aA	<0.001, 182.737
Dryasil+ MLE	4.44±1.75aA	6.66±1.66aA	6.66±1.66cA	0.572, 0.571
Talcum + MLE	0.00±0.00bB	0.00±0.00bB	7.77±1.46cA	<0.001, 28.000
P, $F_{3,32}$	<0.001, 6.400	<0.001, 8.727	<0.001, 75.390	

Means with different lowercase letters in each column and different uppercase letters in each row do not significantly differ using Tukey HSD test at *P* = 0.05, MLE: *Mentha longifolia* extract.

Table 3. Mean mortality% ± SE of *Rhyzopertha dominica* on different surfaces treated with different formulations of diatomaceous earth, 5 days after treatment

Treatments	Concrete	Mosaic	Galvanized steel	*P*, $F_{2,24}$
Silicosec®	15.55±1.75aB	17.77±1.46bB	34.44±1.75bA	<0.001, 43.259
Dryasil	15.55±1.75aC	25.55±1.75aB	44.44±1.75aA	<0.001, 69.733
Dryasil+ MLE	13.33±1.66aB	18.88±1.11bA	23.33±1.66cA	<0.001. 11.091
Talcum + MLE	0.00±0.00bC	7.77±1.46cB	16.66±1.66dA	<0.001, 42.250
P, $F_{3,32}$	<0.001, 25.011	<0.001, 24.905	<0.001, 51.193	

Means with different lowercase letters in each column and different uppercase letters in each row do not significantly differ using Tukey HSD test at *P* = 0.05, MLE: *Mentha longifolia* extract.

On the seventh day after treatment, *R. dominica* adults' mortality was 26.66% when exposed to concrete treated with Silicosec®, which is not significantly different from Dryasil (25.55%). The highest mortality level was recorded on galvanized steel so 54.44% mortality of adults was observed on the surface treated with Dryasil (Table 4).

For *T. confusum*, the mortality percentage was zero on the first day for concrete and mosaic surfaces. On the galvanized steel surface, the mortality percentage was not exceeded 7.77% for Dryasil treatment. In contrast, no mortality was recorded for adults exposed to Dryasil+ MLE and talcum + MLE treated surfaces (Table 5).

On the third day, no *T. confusum* mortality was recorded on the concrete surface. The *T. confusum* mortality percentage did not exceed 5.55% for Silicosec®, Dryasil, and Dryasil + MLE treatments on the mosaic surface. The highest mortality percentage was observed on galvanized steel surface treated with Dryasil, which was significantly different from Silicosec®. The adults' mortality percentage on galvanized steel surface was significantly different from mosaic, except for Dryasil + MLE treatment (Table 6).

There was no significant difference among Silicosec®, Dryasil, and Dryasil + MLE treatments in the mortality percentage of *T. confusum* on the concrete and mosaic surfaces. In comparison, the highest mortality percentage was recorded for *T. confusum* adults exposed to the galvanized steel treated with Dryasil (34.44%), which was significantly more than the mortality caused by a commercial formulation, Silicosec® (Table 7).

After seven days of *T. confusum* adults' exposure to the treated surfaces, the mortality on the concrete surface did not exceed 18.88% for Dryasil and Dryasil + MLE treatments, which was not significantly different from Silicosec®. The mortality percentage was 26.66% when adults were exposed to mosaic treated with Dryasil, significantly more than other treatments. On the galvanized steel, Dryasil had the highest mortality percentage of 45.55%, significantly more than that of the Silicosec® treatment. For all the treatments, the adult mortality was significantly more on galvanized steel than on mosaic and concrete surfaces (Table 8).

Table 4. Mean mortality% ± SE of *Rhyzopertha dominica* on different surfaces treated with different formulations of diatomaceous earth, 7 days after treatment

Treatments	Concrete	Mosaic	Galvanized steel	*P*, $F_{2,24}$
Silicosec®	26.66±1.66aB	32.22±1.46aB	43.33±1.66bA	<0.001, 28.000
Dryasil	25.55±1.75aC	34.44±1.75aB	54.44±1.75aA	<0.001, 69.733
Dryasil+ MLE	23.33±1.66aB	27.77±1.46bA	33.33±1.66cA	<0.001, 9.760
Talcum + MLE	8.88±1.11bC	15.55±1.75cB	25.55±1.75dA	<0.001, 28.500
P, $F_{3,32}$	<0.001, 26.667	<0.001, 27.098	<0.001, 53.439	

Means with different lowercase letters in each column and different uppercase letters in each row do not significantly differ using Tukey HSD test at *P* = 0.05, MLE: *Mentha longifolia* extract.

Table 5. Mean mortality% ± SE of *Tribolium confusum* on different surfaces treated with different formulations of diatomaceous earth, 1 day after treatment

Treatments	Concrete	Mosaic	Galvanized steel	*P*, $F_{2,24}$
Silicosec®	0.00±0.00A	0.00±0.00A	3.33±1.66bA	0.032, 4.000
Dryasil	0.00±0.00B	0.00±0.00B	7.77±1.46aA	<0.001, 28000
Dryasil+ MLE	0.00±0.00	0.00±0.00	0.00±0.00b	-
Talcum + MLE	0.00±0.00	0.00±0.00	0.00±0.00b	-
P, $F_{3,32}$	-	-	<0.001, 11.000	

Means with different lowercase letters in each column and different uppercase letters in each row do not significantly differ using Tukey HSD test at *P* = 0.05, MLE: *Mentha longifolia* extract.

Table 6. Mean mortality% ± SE of *Tribolium confusum* on different surfaces treated with different formulations of diatomaceous earth, 3 days after treatment

Treatments	Concrete	Mosaic	Galvanized steel	P, $F_{2,24}$
Silicosec®	0.00±0.00C	5.55±1.75aB	15.55±1.75bA	<0.001, 30.200
Dryasil	0.00±0.00C	5.55±1.75aB	22.22±1.46aA	<0.001, 76.471
Dryasil+ MLE	0.00±0.00B	5.55±1.75aA	6.66±1.66cA	<0.005, 6.526
Talcum + MLE	0.00±0.00B	0.00±0.00aB	4.44±1.75cA	<0.006, 6.400
P, $F_{3,32}$	-	0.032, 3.333	<0.001, 24.296	

Means with different lowercase letters in each column and different uppercase letters in each row do not significantly differ using Tukey HSD test at P = 0.05, MLE: *Mentha longifolia* extract.

Table 7. Mean mortality% ± SE of *Tribolium confusum* on different surfaces treated with different formulations of diatomaceous earth, 5 days after treatment

Treatments	Concrete	Mosaic	Galvanized steel	P, $F_{2,24}$
Silicosec®	6.66±1.66aB	12.22±1.46aB	26.66±1.66bA	<0.001, 41.440
Dryasil	6.66±1.66aC	17.77±1.46aB	34.44±1.75aA	<0.001, 73.077
Dryasil+ MLE	8.88±2.00aB	16.66±1.66aA	14.44±1.75cA	0.017, 4.875
Talcum + MLE	0.00±0.00bC	5.55±1.75bB	12.22±1.46cA	<0.001, 24.000
P, $F_{3,32}$	<0.001, 6.194	<0.001, 12.081	<0.001, 35.519	

Means with different lowercase letters in each column and different uppercase letters in each row do not significantly differ using Tukey HSD test at P = 0.05, MLE: *Mentha longifolia* extract.

Table 8. Mean mortality% ± SE of *Tribolium confusum* on different surfaces treated with different formulations of diatomaceous earth, 7 days after treatment

Treatments	Concrete	Mosaic	Galvanized steel	P, $F_{2,24}$
Silicosec®	16.66±1.66aB	21.11±1.11bB	35.55±1.75bA	<0.001, 41.217
Dryasil	18.88±1.11aC	26.66±1.66aB	45.55±1.75aA	<0.001, 80.167
Dryasil+ MLE	18.88±1.11aB	22.22±1.46bB	26.66±1.66cA	<0.001, 74.00
Talcum + MLE	5.55±1.75bB	8.88±1.11cB	23.33±1.66cA	<0.001, 37.739
P, $F_{3,32}$	<0.001, 19.556	<0.001, 31.278	<0.001, 33.725	

Means with different lowercase letters in each column and different uppercase letters in each row do not significantly differ using Tukey HSD test at P = 0.05, MLE: *Mentha longifolia* extract.

Discussion

This research showed that the mortality percentage of both insect species was higher on galvanized steel than on mosaic and concrete. This could be attributed to the porous surface of the concrete, which reduced insect exposure to diatomaceous earth particles. Thus, mortality appears to be significantly greater on smooth and polished surfaces than on other surfaces (Delgarm & Ziaee, 2021). In addition, the insecticidal activity of four organophosphorus insecticides (azamethiphos, fenitrothion, chlorpyrifos-methyl, and pirimiphos-methyl) against three species of stored-products insect pests on concrete and galvanized steel surfaces was investigated. The insecticidal effect of the mentioned insecticides was greater on galvanized steel than on concrete (Nayak et al., 2003). Moreover, the insecticidal effect of chlorpyrifos in three concentrations of 0.01, 0.2, and 0.5 g (a.i.)/cm^2 was investigated on concrete, mosaic, and galvanized steel surfaces against *R. dominica* and *T. confusum*. The results indicated that the mortality percentage of two insect species on the surface of galvanized steel was significantly higher than that of concrete and mosaic (Babamir-Satehi et al., 2017). Furthermore, the insecticidal efficacy of commercial formulations, SilicoSec® and Protect-It®, as well as the Iranian formulation of diatomaceous earth, Mamaghan, against *R. dominica* and *T. confusum* adults on concrete, mosaic and galvanized steel surfaces treated with 2.0 mg/cm^2 was evaluated. The results showed that the insecticidal effect and durability of the SilicoSec® commercial formulation on galvanized steel were superior to those of the other formulations tested. In addition, the mortality rate increased proportionally with the duration of adult exposure to the treated surface (Delgarm & Ziaee, 2021).

According to our findings, Dryasil, followed by SilicoSec®, had the highest insecticidal activity against both tested species in most instances. On glass and plastic surfaces, the insecticidal efficacy of SilicoSec® and Diasecticide™ was evaluated at concentrations of 0.5, 1, and 2 mg/cm^2 against adult *Sitophilus granarius* (L.), *T. castaneum* and *Oryzaephilus surinamensis* (L.). The findings indicated that SilicoSec® exhibited the highest insecticidal activity against the tested species. The 2 mg/cm^2 concentration resulted in the highest percentage of adult mortality (Collins & Cook, 2006b). In In another study, the insecticidal efficacy of SilicoSec® at 1 mg/cm^2 and Diasecticide™ at 2 mg/cm^2 against adult *S. granarius* was evaluated on wood surfaces. The results demonstrated that the mortality rate increased proportionally with treatment duration and that the SilicoSec® formulation was more toxic to the adults tested than Diasecticide™ (Collins & Cook, 2006a).

As demonstrated by the results of the current study, in most cases, *M. longifolia* extract did not have a synergistic effect with diatomaceous earth. However, it failed to affect an increase in adult mortality. The combined effects of volatile licorice oil, diatomaceous earth, and kaolin on *R. dominica* adults were investigated in a separate study. The results demonstrated that the volatile oil improved kaolin's insecticidal properties. However, it reduced the effectiveness of diatomaceous earth when combined. According to the authors, adding plant essential oils to diatomaceous earth may reduce the ability of diatomaceous particles to absorb the wax layer of insect cuticles and the activity of diatomaceous earth (Campolo et al., 2014). Our findings were consistent with those of the cited study. Furthermore, the pores of diatomaceous earth may be congested with plant essential oils, reducing its ability to absorb the lipid layer of the insect cuticle (Islam et al., 2010). However, in the studies conducted to date, the results of combining diatomaceous earth with other compounds have varied. For instance, the insecticidal activity of two diatomaceous earth formulations, Silicosec® and Insecto®, was evaluated on adults and larvae of *T. confusum* and larvae of *Ephestia kuehniella* (Zeller) on Petri dishes and concrete surfaces alone or in combination with spinosad. On all surfaces, the toxicity of diatomaceous earth plus spinosad was significantly greater than diatomaceous earth alone (Athanassiou et al., 2018).

The insecticidal activity of Iranian diatomaceous earth, Mamaghan, alone and combined with 15 and 20% nanosilica (synthesized from sugarcane bagasse) was investigated against *R. dominica* and *T. confusum* on concrete, mosaic, and galvanized steel surfaces. The results showed that adding 20% nanosilica to Iranian diatomaceous earth in galvanized steel and mosaic demonstrated the highest insecticidal activity against two tested-insect species (Saed et al., 2020).

Conclusion

The Iranian formulation of Dryasil, followed by the commercial formulation of SilicoSec®, was able to control *R. dominica* and *T. confusum* adults on treated surfaces in most instances. The results indicated that the diatomaceous earth's insecticidal activity increased over time. In most cases, adding *M. longifolia* extract to diatomaceous earth failed to improve the insecticidal efficacy of diatomaceous earth. The galvanized steel surface exhibited the highest mortality rate of the two tested species, followed by mosaic.

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اثر نوع سطح بر کارایی حشره‌کشی خاک دیاتومه ایرانی در مقایسه با فرمولاسیون ®Silicosec علیه حشرات کامل *Rhyzopertha dominica* و شپشه آرد *Tribolium confusum*

فروغ زراسوندی[1]، علی اصغر سراج[2]، معصومه ضیائی[2*]

۱- دانش آموخته کارشناسی ارشد، گروه گیاه‌پزشکی، دانشکده کشاورزی، دانشگاه شهید چمران اهواز، اهواز، ایران.

۲- **نویسنده مسوول**: دانشیار گروه گیاه‌پزشکی، دانشکده کشاورزی، دانشگاه شهید چمران اهواز، اهواز، ایران (m.ziaee@scu.ac.ir)

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چکیده

با توجه به اثرات نامطلوب حشرات آفات انباری و مقاوم شدن آن‌ها در برابر حشره‌کش‌های شیمیایی، شناسایی روش‌های ایمن، مقرون به صرفه و با دوام برای کنترل و کاهش خسارت ناشی از آفات انباری ضروری به نظر می‌رسد. استفاده از خاک دیاتومه یک جایگزین برای آفت‌کش‌های شیمیایی، برای کنترل آفات حشرات محصولات انباری است. این مطالعه فعالیت حشره‌کشی خاک‌های دیاتومه را با غلظت ۰/۲ میلی‌گرم بر سانتی‌متر مربع علیه دو آفت فرآورده‌های انباری، سوسک کشیش (*Rhyzopertha dominica* F.) و شپشه آرد (*Tribolium confusum* Jacqulin Duval) روی سطح‌های بتن، موزاییک و استیل گالوانیزه ارزیابی کرد. برای این منظور سطح‌ها با فرمولاسیون‌های مختلف خاک دیاتومه شامل فرمولاسیون تجاری ®Silicosec، فرمولاسیون ایرانی Dryasil به تنهایی، Dryasil + ۰/۰۵ درصد عصاره پونه (*Mentha longifolia* L.)، و پودر تالک + ۰/۰۵ درصد عصاره پونه تیمار شدند. تلفات ۱، ۳، ۵ و ۷ روز پس از تیمار شمارش شد. آزمایش در دمای ۱±۲۷ درجه سلسیوس، رطوبت نسبی ٥±٦٠ درصد و شرایط تاریکی انجام شد. آزمایش‌ها در ۹ تکرار (۱۰ عدد حشره کامل در هر تکرار) انجام شدند. درصد تلفات سوسک کشیش، ۷ روز پس تیمار با ®Silicosec، Dryasil به تنهایی، Dryasil + ۰/۰۵ درصد عصاره پونه و پودر تالک + ۰/۰۵ درصد عصاره پونه روی استیل گالوانیزه به ترتیب ٤٣/٣٣، ٥٤/٤٤، ٣٣/٣٣، و ٢٥/٥٥ درصد بود. نتایج نشان داد درصد تلفات شپشه آرد روی استیل گالوانیزه به ترتیب ٣٥/٥٥، ٤٥/٥٥، ٢٦/٦٦، و ٢٣/٣٣ درصد بود. درصد تلفات در حشرات کامل شپشه آرد در بیشتر موارد از سوسک کشیش کمتر بود. نتایج نشان داد که اثر حشره‌کشی خاک‌های دیاتومه با گذشت زمان افزایش پیدا کرد. کاربرد خاک‌های دیاتومه به تنهایی، اثر حشره‌کشی بیشتری نسبت به تلفیق آن‌ها با عصاره پونه داشت. بیشترین درصد تلفات حشرات کامل در تمامی تیمارها به ترتیب روی سطح استیل گالوانیزه، موزاییک و سپس بتن ایجاد شد. بنابراین، فرمولاسیون Dryasil را می‌توان برای کنترل آفات فرآورده‌های انباری در سیلوهای غلات استفاده کرد، اگرچه کارایی حشره‌کشی آن بر اساس نوع سطح متفاوت است.

کلید واژه‌ها: *آفات محصولات انباری، بتن، خاک دیاتومه، موزاییک، استیل گالوانیزه*

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