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EFFICACY OF NEW AMORPHOUS SILICA DUST, "DRYACIDE", AGAINST *Sitophilus granarius* (L.) (COLEOPTERA: CURCULIONIDAE) INFESTING STORED WHEAT GRAINS

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ABSTRACT

Amorphous silica dust (Dryacide) was used to control adults of *Sitophilous granarius* at concentrations of 200, 400, 600, 800 and 1000 µg silica dust/g wheat. Adults of *S. granarius* were placed in the three classes of wheat grains (hard, soft & durum)and incubated at 20 °C and 28 ± 1 °C and 65 ± 5 % R.H. Mortality counts were estimated after 48 and 168 hrs. Toxicity increased with increase

lower concentration and temperature. Percent reduction of progeny reached 66.66 – 75.0 % in some wheat classes. Silica dust gave high percentages of mortality after long-term storage at the four periods (1, 8, 16, and 24 weeks) at 500 and 1000 µg/g w. Seed germination was not affected by treatment by silica dust.

INTRODUCTION

Losses caused by insect infestation are the most serious problem in grain storage (Sighamony *et al.,* 1986; Jilani and Saxena, 1990). For more than 30 years, small dosages of synthetic insecticides have been used to protect stored grain from insect infestation, but many stored-grain insects have developed resistance to these insecticides (Parkin, 1965; Zattler, 1974; Champ and Dyte, 1976; Redlinger *et al.*, 1988).

It was found that *Sitophilus granarius* (L.) was considered to be the most economic coleopterous insect. In recent years, attention has been given to the control of stored grain pests using silica dust. It appeared to be a promising on the basis of published data on its use against various stored grain pests (Watters, 1966; La Hue, 1970; Gowers and Le Patourel, 1984; Le Patourel and Singh, 1984; Desmarchelier and Dines, 1987).

The objective of this study was to assess the toxicity of the new amorphous silica dust "dryacide" against *S. granaruis* (L.) which infests three of wheat classes (durum, hard, and soft), its effect on percent progeny reduction, long term storage of wheat and percentage of seed germination.

MATERIAL AND METHODS

The present study was conducted in the laboratory of Girls College of Education in Riyadh, Scientific Departments during 1996-1997. Stock of sensitive S. granarius was cultured in the laboratory on wheat flour from infested wheat obtained from Plant Protection, College of Agriculture, King Saud University in Riyadh for three generations under controlled conditions of 28 ± 1 °C and 65 ± 5 % R.H. The physiochemical properities of Dryacide sorptive (Dryacide Austratia Pty, Ltd) used in this study was as follows:

Colour White, Amorphous silica 92 %, clay contaminates 4 %, Grit 4 %. It is a fine grey dust (95 %>70 µm) with a bulk density of approx. 0.3g/cm³.
After the preliminary tests in laboratory, the following suitable concentrations were used: 200, 400, 600, 800, and 1000 µg/g whole wheat with four replicates for each treatment.

Tests of the toxicity of silica dust to *S. granarius* were conducted on three classes of wheat: hard, soft and durum which were added to 72 clean 500 g jars containing 100 g for each, each variety was added to 24 jars including control. Thus, three groups of jars were obtained. The previous concentrations were added to the jars, three replicates for each, the fourth was left untreated, represented the control. Twenty newly emerged adults from *S. granarius* were placed. The method of Le Patourel and Singh (1984) was used to mix the silica dust with wheat grain. The jars were covered by muslin and tied with rubber bands. Jars were incubated under constant conditions of 20 ± 1 °C and 65 ± 5 % R.H. Another group of 72 jars were prepared as the previously mentioned method, but incubated under constant conditions of 28 ± 1 °C and 65 ± 5 % R.H. Mortality was assessed after 48 and 168 hrs. (2 and 7 days), dead insects were removed after each of the two periods. Mortality counts were corrected by Abbott's formula (Abbott, 1925). The obtained results were used to draw the concentration and dosage mortality regression lines and to calculate the (LC_{50}) and (LC_{90}) values according to the method developed by Finney (1978).

To study the effect of silica dust on progeny reduction, adults from treated and untreated replications in the last experiments were taken from jars at day 7 of exposure. The jars were incubated at 28 ± 1 °C and 60 ± 1 % R.H and were examined twice a week until no further progeny emerged.

$$\% \text{ progeny reductions} = \frac{\text{(No. progeny in control - No. progeny in treatment)}}{\text{No. progeny in control}} \times 100$$

The effect of long-term storage treated with silica dust on its toxicity was tested after 1, 8, 16, and 14 weeks after treatment. Six plastic bags were prepared and filled with 25 kgs. of wheat: hard, soft, and durum. The contents of each bag were mixed with silica dust by two rates of 500 and 1000 µg silica dust gr wheat grain for the first and second respectively. The previous bags were kept under lab. temp. of 28 °C. Similar six bags were prepared with the previous method, but kept under lab temperatures of 20 ± 1 °C. Forty eight (48) jars 1/2 kg were filled with 100g of wheat for each from the previous concentrations with four replicates from each one. One jar was left from each concentration, representing the control. Twenty adults of *S. granarius* were added to each jar after a week and tied with muslin and rubber bands. Mortality was estimated after a week from addition. As the previously mentioned mortality was estimated always after a week from addition of insects, and at the following intervals of storage 1, 8, 16, and 24 weeks post application.

For seed germination, 24 plastic dishes (13 × 18 cm) were prepared by placing 50 treated wheat grains stored for 16 weeks in each dish on a thin layer (2 cm) of sterilized cotton and moistened with water. Grains from the three classes: hard, soft, and durum were treated by 1000 µg/g silica dust

with four replicates from each class (total = 12 dishes). Another 12 dishes with untreated grains were planted as before, representing the control. The same previous investigation was carried out but planted with stored grains for 24 weeks.

Data were statistically analyzed using Duncan (1951) method (analysis of variance, ANOVA).

RESULTS

The toxicities of silica dust to *S. granarius* are presented in table (1). It was clearly observed that toxicity increased with the increase of concentrations after 48 hrs. of exposure in most of treatments of the three wheat classes in an ascending order.

Toxicity decreased according to the increase of temperature in most of treatments (except in 3 cases: hard at "400 and 200 µg/g" and soft at "200 µg/g"). It reached the maximum of all the treatments at the highest concentration (1000 µg/g wh) that was 53.75 % in hard under 20 °C. LC_{50} after 48 hrs. of exposure (table 2) reached the minimum (776.444 µg) in durum, under 20 °C and (1156.616 µg) in durum under 28 °C. Generally LC_{50} and LC_{90} decreased with the decrease of temperature.

Results showed that toxicity of silica dust to *S. granarius* after 168 hrs. (7days) of exposure (table 3), slightly increased with the increase of concentration which it was extremely equal in much of cases (except in one case in soft at 20.25 µg/g at 28°C). The previous result occurred under the two tested degrees of temp. (20 and 28°C). The highest percentage of mortality was 71.25 in case of hard under 28 °C at the highest concentration (1000 µg/g).

Although there were little differences between mortality percentages in the three types of treated wheat under the tested degrees (20 °C and 28 °C), but the LC_{50} values showed clear differences (table 4). These values decreased with the increase in temperature (especially in hard: 626.429 and 289.987, table 4).

Studies of the effect of silica dust on progeny of *S. granarius* (table 5) showed that adults exposed to the dust for 7 days gave progeny in all treated replicates of hard and durum except two only cases (800 µg/g and 1000µg/g respectively). In the last two classes, percent progeny reduction reached 75.0 and 66.66% in hard and durum respectively. This percentage reached 87.50 % in soft at 600 µg/g only. Adults gave progeny in all untreated replicates.

The effect of long-term storage of wheat on the efficiency of silica dust against *S. granarius* (table 6) under the two degrees of temp. (20°C and 28°C) showed that silica dust gave high percentages of mortality after the four periods of storage (1, 8, 16, and 24 weeks) in the three wheat classes, at the two concentrations (500 and 1000 µg/g w). The minimum was 97.5 % in hard at 500 µg/g under 28 °C after 8 weeks of storage. Percentage of mortality reached 100 and 97.5 % for all the tested replicates.

Concerning the effect of long-term storage of wheat treated with silica dust on seed germination, it was found that treated seeds for 16 weeks did

not decrease the percentage of germination compared with the control groups in all tested wheat varieties. Data are illustrated in (figures 5 & 6 and tables 7 & 8). Differences between the three wheat varieties were highly significant after 16 and 24 weeks.

Table (1): Toxicity of silica dust to *S. granrius* (L.) after 48 hrs of exposure.

Concentration (µg/g w)	% Mortality					
	Wheat classes					
	Hard		Soft		Durum	
	20± 1°C	28± 1°C	20± 1°C	28± 1°C	20± 1°C	28± 1°C
1000	53.75	28.75	43.75	31.25	45.00	31.25
800	47.50	27.50	37.50	28.75	45.00	30.00
600	43.75	26.25	33.75	25.00	43.75	31.25
400	22.50	23.75	22.50	21.25	38.75	31.25
200	11.25	20.00	12.50	20.00	21.75	21.75
Control	0	0	0	0	0	0

Table (2): Calculated slopes, LC_{50}, LC_{90} values of silica dust after 48 hrs of exposure.

Category	Wheat classes	Slope		LC_{50}		LC_{90}	
		20± 1°C	28± 1°C	20± 1°C	28± 1°C	20± 1°C	28± 1°C
Mortality of *S.granarius* after 48 hrs under 20 & 28 °C	Hard	1.687	1.598	916.65	1356.186	5866.055	9623.96
	Soft	1.639	1.593	1124.994	1388.072	7593.026	9910.783
	Durum	1.731	1.634	776.444	1156.616	4740.053	7858.66

Table (3): Toxicity of silica dust to *S. granrius* (L.) after 168 hrs (7 days) of exposure.

Concentration (µg/g w)	% Mortality					
	Hard		Soft		Durum	
	20± 1°C	28± 1°C	20± 1°C	28± 1°C	20± 1°C	28± 1°C
1000	46.25	71.25	56.25	68.75	55.00	68.75
800	45.00	70.00	57.50	61.25	55.00	67.50
600	42.50	68.75	57.50	62.50	55.00	68.75
400	41.25	67.50	58.75	62.50	56.25	68.75
200	40.00	68.75	26.25	56.25	55.00	67.50
Control	0	0	0	0	0	0

Table (4): Calculated slopes, LC_{50}, LC_{90} values of silica dust after 168 hrs (7 days) of exposure.

Category	Wheat classes	Slope		LC_{50}*		LC_{90}*	
		20± 1°C	28± 1°C	20± 1°C	28± 1°C	20± 1°C	28± 1°C
Mortality of *S.granarius* after 48 hrs under 20 & 28 °C	Hard	2.223	2.036	626.429	289.987	2562.341	1350.069
	Soft	1.850	1.961	503.112	358.609	2733.737	1770.988
	Durum	1.893	2.022	440.488	300.876	2417.769	1415.870

* = ug/gw = ug silica dust/g wheat grain

Table (5): Effect of silica dust on percent progeny reduction of *S. granrius* (L.) adults exposed for 7 days under 28 ± 1°C & 65 ± 5 R.H.

Dosage (µg/g w)	% Progeny Reduction		
	Hard	Soft	Durum
200	75.0	-	33.33
400	75.0	-	66.66
600	50.0	87.5	66.66
800	-	-	33.33
1000	75.0	-	-
Mean No. Progeny in Control	1.0	2.0	0.75

Table (6): Effect of storage on toxicity of silica dust against *S. granrius* (L.).

Dosage (µg/g w)	% Mortality					
	Wheat classes					
	Soft		Hard		Durum	
	20±1°C	28 ±1°C	20± 1°C	28± 1°C	20± 1°C	28± 1°C
1 week						
500	100.0	98.75	98.0	100.0	98.75	100.0
1000	100.0	100.0	100.0	100.0	100.0	100.0
Control	6.25	11.25	10.0	15.0	10.0	12.5
8 weeks						
500	98.75	98.75	100.0	97.50	98.75	97.50
1000	100.0	97.50	100.0	98.75	100.0	100.0
Control	6.25	5.0	5.0	0	5.0	10.0
16 weeks						
500	100.0	100.0	100.0	100.0	100.0	100.0
1000	100.0	100.0	100.0	100.0	100.0	100.0
Control	6.25	11.25	10.0	10.0	10.0	5.0
24 weeks						
500	100.0	100.0	100.0	100.0	100.0	100.0
1000	100.0	100.0	100.0	100.0	100.0	100.0
Control	5.0	11.25	10.0	15.0	10.0	10.0

Table (7): ANOVA of the effect of silica dust on wheat seed germination after treatment with 1000 µg/g w, stored for 16 weeks

Source	D.F.	Sum of Squares	Mean squares	F Ratio	F Probability
Between groups	2	602.5833	301.2917	3.7600	0.0402
Within groups	21	1682.750	80.1310		
Total	23	2285.3333			

Table (8): ANOVA of the effect of silica dust on wheat seed germination after treatment with 1000 µg/g w, stored for 24 weeks.

Source	D.F.	Sum of squares	Mean squares	F Ratio	F Probability
Between groups	2	390.0833	195.0417	2.5316	0.1035
Within groups	21	1617.8750	77.0417		
Total	23	2007.9583			

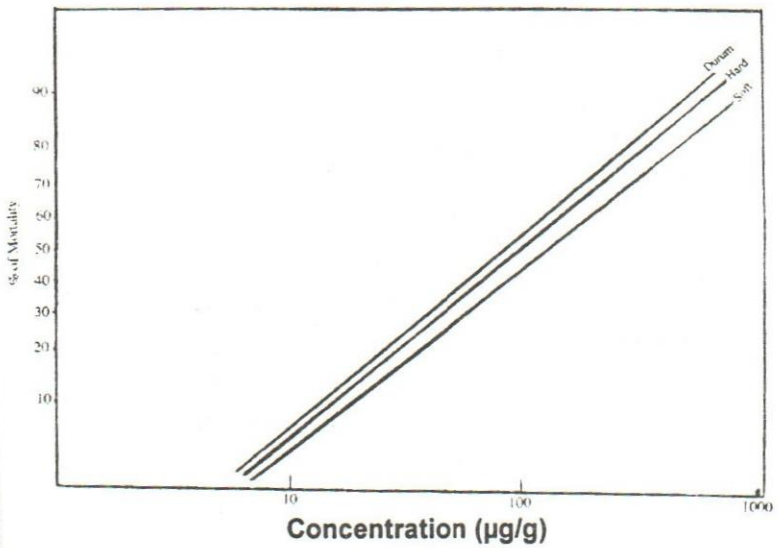

Figure (1): Ld-P mortality line for "Dryacide" against *S. granarius* (L.) under 20 °C after 48 hrs.

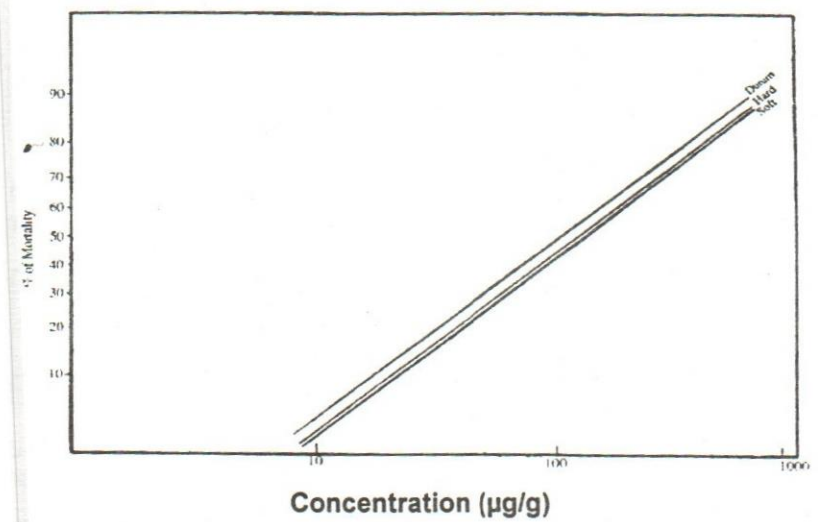

Figure (2): Ld-P mortality line for "Dryacide" against *S. granarius* (L.) under 28 °C after 48 hrs.

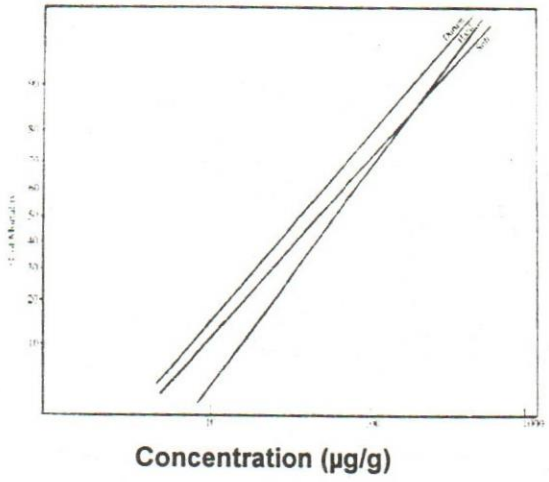

Figure (3): Ld-P mortality line for "Dryacide" against *S. granarius* (L.) under 20 °C after 168 hrs.

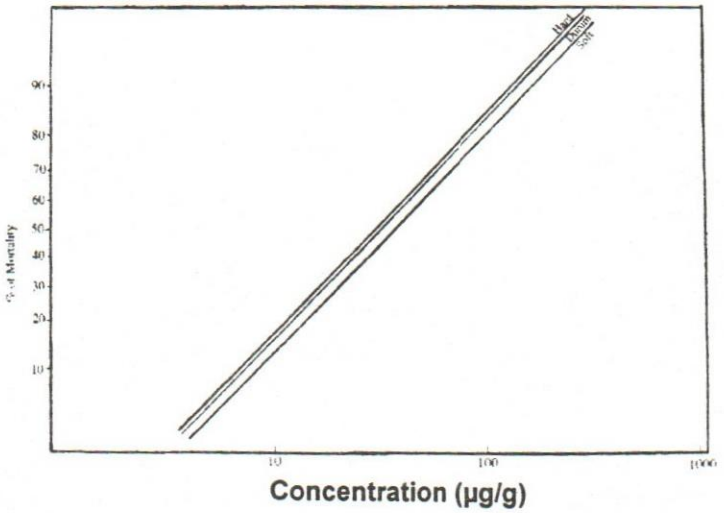

Figure (4): Ld-P mortality line for "Dryacide" against *S. granarius* (L.) under 28 °C after 168 hrs.

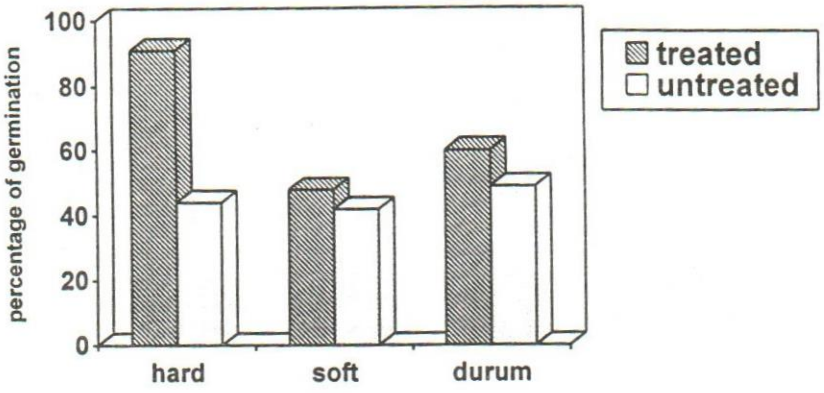

Fig. (5): Effect of silica dust on wheat seed germination after treatment with (1000 µg/g wheat) stored for 16 weeks under 28 °C and 65 % R.H.

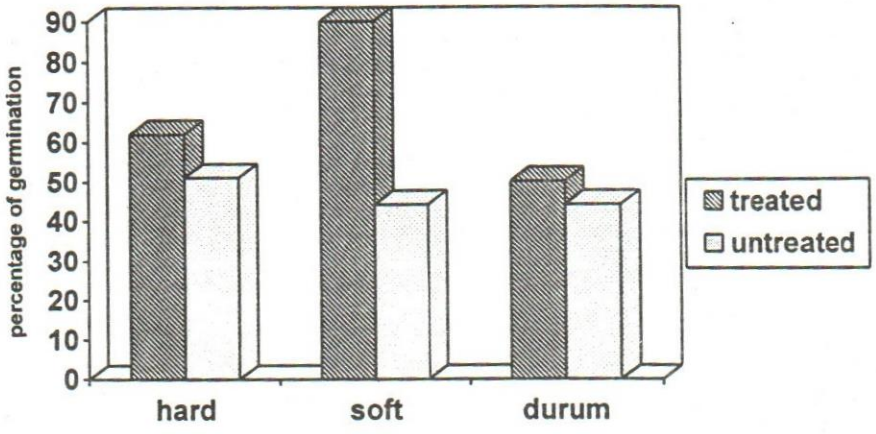

Fig. (6): Effect of Silica dust on wheat seed germination after treatment with (1000 µg/g wheat), stored for 24 weeks, under 28 °C and 65 % R.H.

Discussion:

Synthetic insecticides have been used extensively in controlling stored products insects. Recently, alternative methods are being emphasized to reduce the use of insecticides to lessen the potential for human exposure and to slow the development of insecticide resistance in pests. Silica dust has been used effectively as a grain protectant (Kamel *et al.*, 1964; Ebeling, 1971) with no side effects on grain, flower and dough quality (Aldryhim, 1990; Desmarchelier and Dines, 1987) and no health hazard to humans. However, Loschiavo (1988) speculated that the long-term inhalation of silica particles

may cause respiratory illness in humans. New amorphous dust "Dryacide" has safe advantages according to its heavy molecules. Silica dusts from the inert materials with very small molecules able to absorb fats of insect epicuticle which prevents water evaporation, causing quick loss of insect water content and then death.

It is clear from the present study that silica dust gave high percentages of mortality for *S. granarius* adults especially after a week of exposure. The increase of exposure period from two days to one week caused more efficiency of silica dust measured by LC_{50} values in the three wheat classes: hard, soft and durum under 20 °C reached 1.46, 2.24 and 1.76 times as for a week under the same conditions respectively. Under 28 °C, the increased efficiency was obvious which introduced reduction in LC_{50} values. After two days of exposure, these values reached 4.68, 3.87 & 3.84 times in hard, soft and durum, respectively, as those after a week of exposure.

The present results agreed with Kamel *et al.* (1964) in their experiments on silica aerogel SG-67 (driDi) and SG-68 against coleopterous insects. Also Desmarchelier and Dines (1987) mentioned that mortality percentages of *S. granarius* and *S. oryza* increased greatly after 28 days of exposure than 7 days under the same conditions after treatment with dryacide.

The present study indicated that in both exposure periods (2 & 7 days), percent of mortality correlated positively with the concentration of the dust in all tested replicates. Concerning the effect of the tested wheat classes; hard, soft and durum, in spite that clear differences in LC_{50} values, but the effect of the dust on percentages of mortality of *S. granarius* adults did not show any correlation between the three wheat classes according to LC_{50} values except in one case in which the adults were exposed to silica dust for 48 hrs. under 20 °C and 28 °C. LC_{50} values were in an ascending order, durum, hard and soft. However, this field of investigation needs further studies.

The present study showed that treated wheat with silica dust against *S. granarius* was affected by temperature. Percentages of mortality generally increased by the increase of temperature in most of replicates despite the exposure period. The LC_{50} values decreased under 28°C except few exceptions, when these values decreased (2 days exposure) under 20 °C more than 28 °C.

It is likely suggested that the occurrence of temperature around the optimal conditions to most insects (28 °C) had direct effect on *S. granrius* activity followed by more movement and activity of adult insects, which increased the chances of picking up and attachment of dust molecules, then high percentage of mortality. From this point of view we might not consider that high temperature had an effect on the efficiency of silica dust, thus it is an inert insecticide that differs from other insecticides which might be affected by heat factor. The last results agreed with Shawir *et al.* (1988) in their experiments against *T. confusum* and *S. oryzae*.

On the other hand, the study conducted by Aldryhim (1990) on the effect of silica dust against *S. granaruis* and *T. confusum* indicated that the influence

of temperature on the toxicity of the dust was not fairly understood. He added that the toxicity against *S. granaruis* increased by the increase of temperature, but the opposite occurred in case of *T. confusum*.

S. granarius showed high ability to be affected by silica dust during the short period of exposure (48 hrs.), which might be attributed to its quick nutrition on the treated dust, and then the increase of mortality percentage (Le Patourel and Singh, 1984; Shawir *et al.* 1998).

Also, persistence of silica dust as a non-traditional insecticide was noticed after the exposure of adult insects for 7 days in the three wheat grains, thus, the dust might offer good protection against infestation by a dangerous insect as *S. granaruis* this was evidenced by the clear reduction of progeny percentage resulted from adult insects. This might be attributed to mortality of the female adults before laying enough eggs. Also, it could be added that the newly hatched larvae didn't succeed to complete their life cycle. The present results coincided with those of Aldryhim (1990) in his experiments against *S. granaruis*. Silica dust caused 100 % reduction of the progeny. The present studies indicated that the storage period of the dust might not affect its efficiency, i.e., percent of *S. granaruis* mortality reached 100 % even at the smallest concentration (500 µg/g w.) during the periods: 1, 8, 16, 24 weeks. The differences between the last periods were highly significant (agreed with Kamel *et al*,1964; Aldryhim, 1990)

Concerning the present results about the effect of silica on vitality and seed germination, it was found that they were not affected after dust storage for 6 months. These results are in agreement with Kamel *et al.* (1964) and Aldryhim (1990).

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تأثير مسحوق سيليكا جديدة غير متبلورة (درياســـيد) علـــي سوســـة المخـــزن *Sitophilous granaries (L.)* التي تصيب حبوب القمح المخزونة

البنداري فهد اليوسف

كلية البنات بالرياض – المملكة العربية السعودية

أستعمل مسحوق السيليكا Silica dust (dry acid) لمكافحة الحشـــرات البالغـــة لسوســـة المخزن *S. granaries* وذلـــك بتركـــيزات ٢٠٠ ، ٤٠٠ ، ٦٠٠، ٨٠٠ ، ١٠٠٠ ميكروجـــرام مـــن المسحوق علي دقيق القمح التابع لثلاثة أصناف Hard, Soft and durum. وضعت الحشرات البالغـــة في حضانتين تحت درجتي حرارة ٢٠ ، ٢٨ ±١°م ورطوبة نسبية ٦٥ ± ٥%.

وقد قدرت أعداد الحشرات الميتة بعد ٤٨ ، ١٦٨ ساعة وقد لوحظ أرتفاع النسبة المئوية للمـــوت بزيادة التركيز وكذلك بأنخفاض درجة الحرارة. بلغت النسبة المئوية لنقصان الذرية من ٦٦.٦٦ الـــي ٧٥,٠٠ % في بعض أصناف القمح. أعطي مسحوق السيليكا نسب مرتفعة من موت الحشرات في القمح المعامل بعـــد فترات الحفظ الطويلة ١، ٨ ، ١٦ ، ٢٤ أسبوعا في كلا التركيزين ٥٠٠ ، ١٠٠٠ ميكروجرام/ جـــرام وزن هذا ولم تؤثر المعاملة علي نسبة أنبات حبوب القمح.