Insecticidal effects of siliceous sands as preservative for maize and cowpea storage

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ABSTRACT

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Siliceous sands were tested in maize and cowpea storage against pests. The purpose of this study is to evaluate the insecticidal activity of two sands applied at increased doses of 1, 2, 3 and 4g/250g of maize and cowpea on *Sitophilus zeamais*, *Callosobruchus maculatus*, *Prostephanus truncatus* and *Tribolium castaneum* adults. Sands (Diobe1 and 2) were sieved and the two particles sizes retained for the study were 1×1 mm and 0.3×0.3 mm. Untreated plots and Actellic® served as control and the experiment was conducted during one month. Each dose was repeated 4 times. Results revealed a high efficiency of siliceous sand against these four pests with greater efficiency of Diobe1. Mortality of 85% was observed with Diobe 1 against 100% for actellic® and 0% for untreated plots. Emergences progressed inversely to the mortality. Damage and losses reached respectively 25% and 6% with untreated plots. *P. truncatus* caused nearly 16% of damages and 3% of losses at lower doses. However, with 4g/250g of stored substances (1.6%, w/w), the losses were below 1%. Insects did not show the same sensitivity to treatment and fineness of particles sands inhibits their action as long as the dose increases.

Keywords: Cowpea, insecticidal activity, maize, pests, siliceous sands, storage

Legumes and cereals are the main staple food sources in many parts of the world especially inSahel where malnutrition continues to persist with a prevalence rate estimated at 24.8% between 2011 and 2013 (FAO, FIDA, PAM 2009). The cowpea (*Vigna unguiculata*), is a leading global food legume, particularly in the arid savannahs of West Africa. Its seeds are a valuable source of vegetable protein, vitamins, and incomes for humans and fodder for animals. Furthermore, the cowpea plays an important role as a nitrogen source on cereal crops such as millet, sorghum and maize (Dugye et al. 2009). Louga and Saint-Louis are the main Senegalese growing regions with about 65% of Senegalese production (Cissé and Hall 2001). Maize (*Zea mays*) has become one

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of the main cereals next to rice and wheat. World production of maize in 2016 was estimated at 839 million tons compared to the previous year with 860 million tons (Planetoscope 2015). In the least developed countries, particularly in Africa, maize is a food crop especially intended for human and animal consumption, but also used by agribusiness. In Senegal, maize is the most important cereal after millet and rice. Maize grows in the southern and east regions; it is irrigated in the groundnut basin and the Senegal River Valley (Guèye et al. 2010).

In field, maize is threatened by numerous abiotic and biotic factors (Guèye et al. 2010; Hayma 2004). Insects' damage on stored products is a major problem which can induce significant losses. Also, the cowpea weevil, *Callosobruchus maculatus* and the larger grain borer *Prostephanus truncatus* can cause complete loss within three to six months if the storage is not adequate (Amoivine et al. 2007; Guèye et al. 2012).

To address such problems, pesticides are often used for the protection of stored products. While it is true that pesticides contributed to the increase in food production over the last 50 years, the fact remains that their use is limited by many constraints. Pest resistance (Charaabi et al. 2016), discovery of carcinogenic and environment pollution caused pesticide issues (Maumbe and Swinton 2003; World Health Organization 2008).

All these complaints brought against pesticides require the exploration of alternative methods of storage which are more efficient and less polluting. For this purpose, many studies have been undertaken in recent years in Senegal to offer local ecofriendly alternative solutions based on the biodiversity exploitation (Cissokho et al. 2015, Guèye et al. 2013; Seck et al. 1993). The objective of this study is to test the effectiveness of two inert dusts (silica sands) from Senegal against adults of *Sitophilus zeamais*, *C. maculatus*, *Tribolium castaneum*, and *P. truncatus*, in the maize and cowpea storage.

MATERIALS AND METHODS

Plant material.

Grains of cowpea and maize were purchased from a local market in Dakar (Senegal). To avoid an insect infestation, the maize and cowpea grains were placed in polyethylene bags and stored in a freezer at a temperature of -4 °C for two weeks. Finally, they were re-exposed to ambient laboratory conditions before use. Grains showing any kind of damage were discarded. Maize grains were used for tests with *S. zeamais*, *T. castaneum* and *P. truncatus* and cowpea grains with *C. maculatus*.

Inert dusts.

Inert dusts in a form of siliceous sands were used from Matam,a region in the north of Senegal. They were collected at Diobe hill (Foumé Hara Diobé) located in the north west of this area (N 15 ° 27.022 / W 13 ° 11.116). Both silica sands are from the same out crop, but from different locations (Fig. 1). Diobe 1 was taken at 2 meters from the up stream of the exposure while Diobe 2 was collected at 2.5 meters from the latter. Both substances were ground, put through a sieve 0,3 mm and 1 mm and kept in the laboratory at room temperature.

Both powdered fractions were kept in individual polyethylene bags and placed at ambient temperature and relative humidity. In addition, chemical analysis by fluorescence was performed.

Insect rearing.

S. zeamais, C. maculatus, P. truncatus, *T. castaneum* adults came from a breeding ground and maintained in the laboratory at 27 ± 1 °C and 70 ± 5% RH for at least 4 generations in one-liter glass jars. Insects used in the tests were young, emerging up to 48 hours before experiment's start.

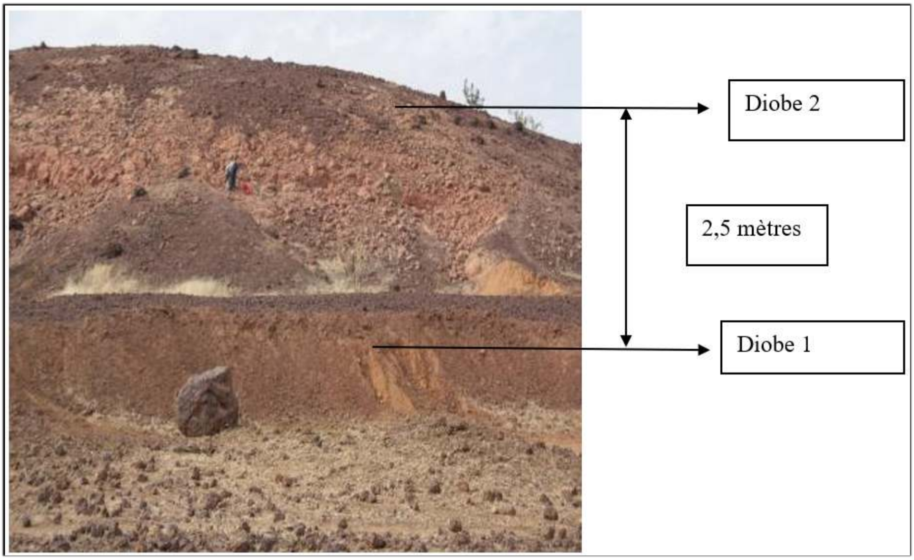

Fig. 1. Dusts collection sites for Diobe 1 and Diobe 2 samples.

Chemical material.

Actellic® Super Dust is a broad-spectrum insecticide composed of 16g/kg pirimiphos-methyl and 3g/kg permethrin served as positive control. It is used as protectant for stored products but also for disinfection of storage facilities. It controls most pests, including beetles, moths, and mites. Actellic® is active on larval and adult forms of pests by contact, ingestion, and inhalation.

Experimental procedures.

Adults of the 4 insect species namely *S. zeamais*, *C. maculatus*, *P. truncatus* and *T. castaneum* were tested. The tests were carried out in jars with a capacity of 1 liter, each containing 250 g of maize grains or cowpea with moisture content below 11% and siliceous sands. To achieve uniform distribution of the powder on the grains, the jars were agitated manually for 2 to 3 minutes, and then stabilized 8 to 10 minutes, until all the particles settled, then 20 young unsexed adults were added to each jar.

For each type of siliceous sands, Diobe1 and Diobe2 respectively, two sizes refusals sieve (1 and 0.3 mm) were considered and tested doses were 1, 2, 3 and 4 g/250 g of stored substrate. The experimental design consisted of a completely randomized block design with 12 treatments (glass jars) and 4 replicates for the purpose of statistical analysis. The treatments included 2 controls, one treated with Actellic® and the second untreated control. Actellic® insecticide retained to the recommended dose of 50g/100kg whether 0,125 g/250 g (Table 1).

Table 1. Treatment design of siliceous sands

Treatments	Particles size (mm)	Dose (g/250 g maize)
T_1 (untreated)	—	—
T_2 (treated with Actellic®)	—	0,125g
T_3	1	1
T_4	0,3	1
T_5	1	2
T_6	0,3	2
T_7	1	3
T_8	0,3	3
T_9	1	4
T_{10}	0,3	4

Mortality and first generation evaluation (F1).

The mortality monitoring was conduced over a period of 14 days. Thedead individuals were counted and removed daily.

Evaluation was achieved on the first generation (F_1) by counting the numbers of offspring of all treatments in a month and 14 days. To do this, the substrate, the powder, and the insects were separated using screens, and emerged insects were counted. Abbott's formula (1925) was used to correct mortalities.

Damage and loss estimated.

The percentage of damage is determined by taking the ratio of the number of damaged grainson the total number of grains:

$$\text{Damage (\%)} = \frac{\text{Number of damaged grains}}{\text{Total number of grains}} \times 100$$

Loss percentage is calculated using the Boxall formula (1986):

$$\%Losses = \frac{(\text{E x B}) - (\text{C x D})}{(\text{ExA})} \times 100$$

Where A is the total number of grains; B, the number of infested grains; C, the number of healthy grains; D, the weight of infested grains; and E, the weight of healthy grains.

Statistical analysis.

All data were reported as mean of 4 replicates for biological activities of siliceous sands. The data were subjected to variance analysis (ANOVA) on XL-STAT 6.1.9. The Tukey test was used for the separation medium significantly different treatments.

RESULTS

Dust composition.

Results show percentage differences between the components of the 2 silica sands Diobe1 and Diobe2 (Table 2). This table shows essentially siliceous nature of the sands with moderate contents of alumina, iron oxide, magnesium oxide and calcium oxide. Silica content varies according to the sand. Diobe2 with silica content 75.4% is richer than Diobe1 which contains 52.2% silica. But Diobe1 is richer in alumina (27.79%) and iron oxide (4.17%) than Diobe2.

Table 2. Chemical composition of siliceous sands for Diobe1 and Diobe2 (%)

Chemicals	Diobe 1	Diobe 2
SiO_2	52,19	75,47
TiO_2	0,70	1,35
Al_2O_3	27,79	12,82
Fe_2O_3	4,17	0,67
MnO	0,01	0,00
MgO	0,00	0,00
CaO	0,11	0,16
Na_2O	0,00	0,00
K_2O	0,09	0,01
P_2O_5	0,27	0,02
LOI	12,11	7,70
SUM	97,44	98,20
Zr	0,1	0,2
Cl	-	0,1
Sr	0,3	-
Ce	0,1	-
S	0,1	-
La	0,1	-
Total	98,14	98,50

Assessing adult mortality.

Results are reported in Table 3. No mortality was observed in the untreated control, while treatments in Actellic® achieved 100% mortality after 24 hours of testing. For Diobe1 bioassays, mortalities in the treatments T_3, T_4 and T_5 were very low, below 10% for the tested insects except *C. maculatus* with T_4, where the mortality was 68.3%. Indeed, *C. maculatus* remains substantially affected in the same way when the dose was increased to a maximum of mortality with T_{10}, 85%. The sensitivity of other insects was observed especially from T_6. For *S. zeamais*, mortality increased with the dosages and also depended on the particle size. For the same dose, the fineness of the particles was important on the level of mortality. *P. truncatus* and *T. castaneum* were more tolerant to treatments.

Mortalities between 10 and 20% are rated from T_8 with the rejection of 0.3mm only.

C. maculatus was as the most sensitive insect to treatment of Diobe2 sand. Mortalities were low between T_3 and T_6 with significantly better action with the 0.3mm diameter. T_7 to T_{10}, both particle sizes gave the same result, whether mortality rates were about 60%. *S. zeamais* behaved in the same way as *C. maculatus* with greater tolerance. It is also more sensitive to fine sand. The T_{10} treatment gave the best rate with almost 60% mortality. *P. truncatus* and *T. castaneum* are not affected by the silica sand Diobe 2. Mortality rates were below 5% and higher doses have acted as somewhat insignificantly.

Table 3. Effects of siliceous sands Diobe1 and 2 on adult insect's mortality (%)

Insect Treatment	*S. zeamais*		*C. maculatus*		*P. truncatus*		*T. castaneum*	
	Diobe1	**Diobe2**	**Diobe1**	**Diobe2**	**Diobe1**	**Diobe2**	**Diobe1**	**Diobe2**
T_1	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a
T_2	100 d	100 e	100 d	100 d	100 d	100 d	100 c	100 d
T_3	5.51 a	4.8 ab	4.12 a	8.4 a	1.4 a	1.2 ab	1.8 a	0.7 ab
T_4	5.42 a	5.1 ab	68.3 c	23.3 ab	4.5 a	2.7 ab	4.1 a	1.6 ab
T_5	5.68 a	4.8 ab	8.2 a	8.2 a	1.4 a	2.2 ab	1.8 a	1.8 ab
T_6	32.4 b	20.3 c	72.1 c	43.3 bc	5.5 ab	3.9 ab	5.9 a	2.4 ab
T_7	23.8 b	5.2 ab	30.3 b	30.1 abc	3.0 a	2.4 ab	4.3 a	1.8 ab
T_8	69c	45.6 d	72.4 c	61.5 c	19.5 c	3.4 ab	21.5 b	4 c
T_9	38.3 b	18.3 bc	42.8 b	61.3 c	3.8 a	3 ab	3.9 a	2.3 bc
T_{10}	72.6 c	58 d	87.1 cd	59.8 c	13.4 bc	7.1 c	22.4 b	3.9 c

Mortality percentages in same column followed by identical letters are not significantly different ($P<0.05$).

Effects of siliceous sands on emergences.

Table 4 reported results of the effects of siliceous sands on insect emergence. After one month, the emergence rates showed significant differences between insects. Indeed, *C. maculatus* gave the largest rate of progenies with 174 individuals, followed by *P. truncatus* and *S. zeamais* with respectively 97 and 78 individuals. Regarding *T. castaneum*, only 14 insects emerged in F_1. Treatment with Actellic® prevented the proliferation of insects. *P. truncatus* gave the highest number of progenies (nearly 60 T_3 and T_5) with treatments Diobe1 sand. For a given dose and insect, emergences were not significantly different for a given particle size. Overall, the number of emerged insectswasbelow 10 individuals. With regard to the treatments with sand Diobe 2, it appears that the analysis showed no statistical differences between Diobe2 sand for all insects (*S. zeamais*, *C. maculatus*, *P. truncatus* and *T. castaneum*). According to Wilks test, siliceous sands Diobe1 and Diobe2 have effect on the rate of emergence of different insect (F=1.35 and P = 0.0132).

Indeed, for the same insect and at the same dose, the analysis showed no statistical differences. Moreover, in the tested range, higher doses do not induce significant differences in emergence rates.

P. truncatus and *S. zeamais* gave the greatest rate of emergence for all doses with maxima of around 50 individuals. The number of *S. zeamais* emerged in F1 is statistically the same for all doses and the maximum is below 50 individuals. It is note worthy that *C. maculatus* does not emerge from T_6 to T_{10} except T_7. As for *T. castaneum*, whatever the dose, emergence have been very low, most often less than 10 individuals.

Table 4. Rate of emergence (F_1 progenies) of insects on maize and cowpea grains treated with siliceous sands Diobe1 and 2 for different treatments

Insect Treatment	*S. zeamais*		*C. maculatus*		*P. truncatus*		*T. castaneum*	
	Diobe1	Diobe2	Diobe1	Diobe2	Diobe1	Diobe2	Diobe1	Diobe2
T_1	78.2 c	78.2 c	173.5 b	173.5 b	96.5 b	96.5 b	13.7 b	13.7 c
T_2	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a
T_3	14.7 b	48.2 bc	14.7 a	34.5 a	56.2 ab	52.5 ab	4.2 a	5 abc
T_4	7 ab	42 bc	3 a	4,2 a	38,5 ab	32,2 ab	1.5 a	9.2 bc
T_5	5.5 ab	27.2 ab	7.5 a	19 a	58,7 ab	48 ab	4.2 a	7 abc
T_6	3.7 a	24.5 ab	1.7 a	0 a	21.2 a	16.2 a	1 a	3.7 ab
T_7	6.7 ab	17.2 ab	14 a	18.5 a	42.7 ab	35.7 ab	5.2 ab	4.2 ab
T_8	0 a	23.7 ab	0 a	0 a	3.25 a	29.5 a	0.2 a	3.7 ab
T_9	8.2 ab	11.5 ab	2 a	0 a	21.7 a	41 ab	3.5 a	8 abc
T_{10}	0 a	12.7 ab	0 a	0 a	6 a	9.5 a	0 a	2 ab

Means emergences with the same letters in a column (between one sand and one insect) are not significantly different at $P < 0.05$.

Effects of siliceous sandson the damage caused by insects.

Results of siliceous sands on damage are shown in Table 5. In the control, after one month, the damage estimation showed that *P. truncatus* was the most active among the tested pests with 25.7%, followed by *C. maculatus* (15.6%), *S. zeamais* (10.6%) and *T. castaneum* (5.6%). However, with Actellic®, no damage was observed for any insect. As for the control, *P. truncatus* caused the most damage (16.5%) on maize treated with Diobe1 sand. It also appears that beyond the dose of 1g and 0.3mm size (T_4), particle size appears important because a significant difference was noted between the treated groups with the refusal of 0.3mm and 1mm. The finest silica sand showed the lowest damage and the minimum was observed, with T_{10} (less than 5%). *S. zeamais* caused damage of around 5% between T_3 and T_9 given the size of the inert substance, and damage is virtually zero to T_{10}. *T. castaneum* shows the same profile as *S. zeamais* with lower damage whose maxima were below 5%. *C. maculatus* caused damage of around 5% between T_3 and T_5 (between 1 and 3%). With Diobe2, *T. castaneum* and *C. maculatus* caused less damage in all treatments. Moreover, damage caused by *S. zeamais* varied between 6.6 and 1.8% in T3 to T_{10}. The difference in particle size had effect (F=1.48 and P = 0.0172). As Diobe1, higher damage percentages were recorded with *P. truncatus* 14% for T_3; 12.7 and 10.4% for T_5 to T_7. T_{10} had a same efficacy than Actellic® and was significantly more effective in limiting the damage with 0.1% minimum damage caused by *S. zeamais* in Diobe1.

Table 5. Effects of siliceous sands Diobe1 and 2 on the damage (%) caused by insects according to treatments

Insect Treatment	*S. zeamais*		*C. maculatus*		*P. truncatus*		*T. castaneum*	
	Diobe1	Diobe2	Diobe1	Diobe2	Diobe1	Diobe2	Diobe1	Diobe2
T_1	10.6 e	10.6 d	16.1 e	16.1 c	25.7 d	25.7 f	5.2 d	5.2 e
T_2	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a
T_3	5.7 d	6.6 c	5.2 cd	6 b	16.3 c	14 e	2.9 c	3.2 bcd
T_4	4.1 bcd	5.9 c	4.2 bcd	1.4 a	12.0 bc	9.2 bcde	1.8 abc	3.2 cd
T_5	3.6 bc	5.5 c	5,4 d	1.3 a	16.4 c	12.7 de	2.2 bc	3.5 d
T_6	2.4 b	4.2 bc	1,2 ab	0.6 a	7.7 ab	8 bcd	0.7 ab	2.4 bcd
T_7	4.2 bcd	3.7 bc	1.2 ab	2.4 a	14.6 bc	10.4 cde	2.2 bc	2.2 bcd
T_8	0.4 a	3.9 bc	1.0 ab	0.3 a	2.5 a	6.2 bc	1.3 abc	1.6 abc
T_9	4.9 cd	1.2 ab	1.9 abc	0.4 a	7.5 ab	10 cde	2.0 bc	3.2 cd
T_{10}	0.1 a	1.8 ab	0.4 a	0.3 a	2.5 a	3.6 ab	1.2 abc	1.4 ab

Means damage (%) followed by identical letters percentages in a column (between one sand and one insect) are not significantly different ($P < 0.05$).

Effects of siliceous sands on the weight losses caused by insects.

Results related to sand treatment impacts on weight losses are reported in Table 6. Results of Diobe1 and 2 treatments showed that *P. truncatus* (6%) and *C. maculatus* (5.6%) caused the greatest losses. *S. zeamais* and *T. castaneum* have caused respectively 2.6 and 1% losses. No loss was registered with Actellic® treatments. As for silica sand Diobe1, *P. truncatus* has caused the greatest losses in treated groups. Higher doses had a positive impact on reducing losses. The importance of fineness of the particle size appears beyond T_7 with losses less than 1% against more than 3% to the T_3 dose. *S. zeamais* and *C. maculatus* have the same profile with negligible losses especially to the particle size 0.3 mm against losses between 0.5 and 1% for doses between T_3 and T_6. Losses caused by *T. castaneum* fall below 1% and vary significantly with low doses and sizes. Regarding Diobe2 treatments, the particle size of silica sand showed little significant effect ofa given dose (*S. zeamais*, *C. maculatus*, *P. truncatus* and *T. castaneum* have caused respectively 0.36, 0.05, 0.61 and 0.22% losses toT_{10}). In addition, increasing the dosage did not result in a significant decrease in losses.For *S. zeamais, C. maculatus* and *T. castaneum* induced losses below 1%, especially beyond T_4. The losses were insignificant with increasing doses. According to Wilks test, there is significant action on the particle size noted in these insect (F=1.26 and P = 0.0072).

Table 6. Effects of siliceous sands Diobe1 and 2 treatments on weight losses (%) caused by insects

Insect Treatment	*S. zeamais*		*C. maculatus*		*P. truncatus*		*T. castaneum*	
	Diobe1	**Diobe2**	**Diobe1**	**Diobe 2**	**Diobe1**	**Diobe2**	**Diobe1**	**Diobe2**
T_1	2.6 e	2.6 f	5.6 c	5.6 c	6 e	6 e	1.02 d	1.02 e
T_2	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a
T_3	1.46 d	1.43 e	0.92 ab	1.52 b	3.41 d	2.93 d	0.63 cd	0.76 de
T_4	1.02 bcd	1.29 de	0.8 ab	0.29 a	2.01 bcd	1.69 bcd	0.36 abc	0.66 cd
T_5	0.82 bc	1.08 cde	1.16 ab	0.24 a	3.14 d	2.77 cd	0.48 bc	0.75 de
T_6	0.49 ab	0.8 bcde	0.25 ab	0.09 a	1.26 abc	1,36 abc	0.12 ab	0.42 bcd
T_7	0.94 bcd	0.65abcd	0.19 ab	0.5 ab	2.77 cd	1.99 bcd	0.4 abc	0.43 bcd
T_8	0.08 a	0.72abcde	0.15 a	0.04 a	0.49 ab	1.07 ab	0.19 ab	0.3 abc
T_9	1.14 cd	0.22 ab	0.31 ab	0.06 a	1.45 abc	1.98 bcd	0.46 bc	0.7 cde
T_{10}	0.01 a	0.36 abc	0.04 a	0.05 a	0.42 ab	0.61 ab	0.18 ab	0.22 ab

Means losses (%) followed by identical letters percentages in a column (between one sand and one insect) are not significantly different at $P < 0.05$.

DISCUSSION

The results presented in this study showed that both silica sands reveal interesting properties in protecting maize and cowpea against attacks caused by *S. zeamais*, *C. maculatus*, *T. castaneum* and to a lesser extent *P. truncatus*. High mortality of *C. maculatus* with silica sand Diobe1 was achieved. In light of the results, it appears that with doses of more than 4% (w/w) and a particle size in the range of 0.3 mm, silica sand (Diobe1) could potentially be considered as a substitute for pesticides in the conservation of maize and cowpea seeds. The sands have given high levels of control depending on the insect. Similar performances are noted on *S. zeamais* which is also particularly sensitive to the fineness of the particles where it is noted to cause higher mortality with the finer particle size. The silica sands have less effect on the survival of *P. truncatus* and *T. castaneum* adults. Indeed, the ability of silica sand to kill the adults of the first generation plays a key role in the infestation levels of stocks, especially for long term storage. Athanassiou et al. (2003) showed in rice, maize and wheat considerable variation in the efficacy of SilicoSec®, a freshwater diatomaceous earth composed of 92% silica against *S. oryzae* with doses ranging from 0.125 to 1.5 g/kg depending on grain, exposure time, and dose. It has revealed unsatisfactory efficacy on maize with non-significant emergence rates. Vayias et al. (2006) found that diatomaceous earth is much more effective when applied to wheat rather than maize. The wide spaces between the grains of maize could allow insects to move and avoid areas where the concentration of diatomaceous earth is high. Hertlein et al. (2011) also highlighted the sensitivity of *S. zeamais* with diatomaceous earth. According to Mulungu et al. (2010), *P. truncatus* adults penetrate grains most of the time, so are less exposed to the ground than adults of *S. zeamais* remaining on the surface of the grain. These observations are consistent with the higher damage caused by *P. truncatus*. Kavallieratos et al. (2010) showed that *T. confusum* was less sensitive than *Rhyzopertha dominica* and *S. oryzae* to three protectants diatomaceous formulations (SilicoSec® and Insecto®) and Spinosad. Arnaud etal. (2005) have meanwhile demonstrated a significant difference between sensitivity of several populations of *T. castaneum* towards four diatomaceous earth formulations. Based on these results, it appears that the greater sensitivity of *C. maculatus* could come from either better adhesion of the particles of silica sands to cowpea, or a greater sensitivity of this insect compared to other tested pests. Moreover, *T. castaneum* has weak predatory action which is probably due to its status as secondary pest of maize. Its low ability to penetrate healthy grains lengthens its larval development according to low damage and loss.

Levels of emergences are opposed to the importance of mortality. The latter is significantly correlated with the fineness of particles. In many cases, lower doses with finer particle size gave higher mortality rates and correspondingly lower emergence. Losses have thus evolved in parallel with the severity of the infestation. *P. truncatus* caused 25% of damage and 6% of loss and confirmed its status as a major driller. Indeed, *P. truncatus* could generate loss of more than 3% at non-effective doses. However, it should be noted that with the insect multiplication potential and voracious nature of both larvae and adults, unprotected maize can be completely destroyed in a few months of storage. Its adaptation to cassava, sorghum, and possibilities to live in softwood silos makes it more dangerous insect. In this regard, Holst et al. (2000) reported that drilling caused by *P. truncatus* adults destroyed four times more than the larva consumption. Its presence in southern and eastern Senegal has been reported (Guèye et al. 2008). Therefore, increased monitoring is required to curb its spread in the country.

It is commonly accepted that the proportion of SiO_2 largely determines the efficacy of inert dusts such as diatomaceous earths. However, this is not the case for our siliceous sands where silica sand Diobe1 (despite its SiO_2 content being less than Diobe2) was more effective for the 4 insect species. This is probably due tothe difference of physical properties such as a high percentage of fine particles, a pH less than 8.5, and a density less than 300g/l (Korunic 1997). There is broad consensus on the mode of inert dusts action. They erode the layer of cuticular waxes of insects leading to death of the insect by drying (Korunic et al. 1996; Subramanyam and Roesli 2000). According to Mewis and Ulrichs (2001), contact between diatomaceous earth and *S. granarius*, *T. molitor* and *T. confusum* led to the loss of weight for adults and a reduction in body water content, which implies barrier disruption which retained water in the insect. However, some factors are known to adversely affect the efficacy of inert dusts such as water content of the grain, relative humidity, type of insect (morphology and shape) and temperature (Athanassiou and Steenberg 2007). In contrast to moisture, temperature increase enhances the activity of diatomaceous earth (Vayias and Stephou 2009).

Siliceous sands applications against *S. zeamais*, *C. maculatus*, *P. truncatus*, and *T. castaneum* have shown convincing results. In some cases, the efficacy of silica sands depends on the sensitivity of species, the fineness of particles, and the applied dose. Furthermore, Actellic® remains fully effective against insects of stored foodstuffs. The tested doses which did not exceed 4g/250g grains, gave a very good control with adult pests (1.6%). The matrix size has also proved very important. Indeed, with a diameter of silica sand particles smaller than 0.3mm, insect survival is strongly affected and subsequently the damage and loss tend to zero with increased doses. *P. truncatus* proved less sensitive responses to treatments. Thus, in a perspective of integrated pest management, higher doses of 2-3% should circumscribe the action of all pests and allow for a greater conservation of maize and cowpea. In the light of the obtained results, we can consider substituting synthetic pesticides in the conservation of stocks of maize and cowpea seeds especially by the application of silica sand.

RESUME

Cissokho P.S., Welle F., Gueye M.T, Diarra K., Sow E.H. et Lognay G. 2018. Effets insecticides des sables siliceux comme conservateurs pour le stockage du maïs et du niébé. Tunisian Journal of Plant Protection 13 (2): 229-241.

Des sables siliceux ont été testés en vue du stockage du maïset du niébé contre les insectes ravageurs de stocks. Leur activité insecticide a été évaluée par application de doses croissantes de 1, 2, 3 et 4g/250g de denrées sur les adultes de *Sitophilus zeamais*, *Callosobruchus maculatus*, *Prostephanus truncatus* et *Tribolium castaneum*. Pour chaque sable siliceux, Diobe1 et2, les refus desdeux tamis de 0,3 mm et 1 mm ont été retenues. L'Actellic® et des lots non traités ont servi de témoins. Chaque dose est répétée 4 fois. Après un mois, les résultats ont montré une grande efficacité des sables siliceux à l'égard de ces 4espèces d'insectes. Diobe1 s'est montré plus efficace avec des mortalités de 85% contre 100% pour l'Actellic® et 0% pour les lots non traités. Les émergences ont évolué inversement à la mortalité. Les dégâts et pertes pondérales ont atteint respectivement 25 et 6% en l'absence de traitement. *P. truncatus* a occasionné près de 16% de dégâts et 3% de pertes pondérales aux plus faibles doses. Cependant, avec la dose 4g/250g de denrées (1,6%, p/p), les pertes sont en dessous de 1%. Les insectes n'ont pas montré la même sensibilité et la finesse des particules des sables inhibe leur action quand les doses augmentent.

Mots clés: Activité insecticide, insectes ravageurs, maïs, niébé, sable siliceux, stockage

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ملخص

سيسّو و،باب ساينيوفاتو وال وموماړ تالاّ وكاراموكو ديارّا والحاجي سو وجورج ونياي. 2018. تأثيرات مثل المبيدات الحشرية للرمال السيليزية الحافظة للذُرة واللوبيا أثناء التخزين.
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تمت تجربة رمال سيليزية أثناء تخزين الذُرة واللوبيا ضد حشرات الخزن. تم تقييم نشاط هذه الرمال المشابه لمبيدات الحشرية باستعمالها بجرعات متزايدة 1 و 2 و 3 و 4 غ/250 غ من المادة المخزنة على الحشرات البالغة *Sitophilus zeamais* و *Callosobruchus maculatus* و *Prostephanus truncatus* و *Tribolium castaneum*. لكل رمل سيليزي، ديوبال1 و 2، تم اعتماد سواقط غرباليْن اثنيْن لـ 3 مم و 1 مم. تم استعمال المبيد الحشري أكتاليك® والحصص غير المعاملة كشواهد. أعيدت كل جرعة 4 مرات. بعد شهر واحد، بينت النتائج نجاعة كبيرة للرمال السيليزية تجاه الأنواع الأربعة للحشرات. تبين أن ديوبال1 له أكثر نجاعة بنسبة وفيات 85% مقابل 100% للمبيد أكتاليك® و 0% للحصص غير المعاملة. وأظهر البروز تطور معاكس لنسبة الوفيات. وصلت الأضرار والخسائر في الوزن على التوالي 25 و 6% في غياب المعاملة. تسببت الحشرة *P. truncatus* في أضرار تقارب 16% وخسائر في الوزن 3% مع الجرعات الصغيرة. رغم ذلك، مع الجرعة 4 غ/250 غ من المادة المخزنة (1,6%، وزن/وزن)، كانت الخسائر أقل من 1%. لم تظهر الحشرات نفس الحساسية وكانت نعومة جسيمات الرمال تمنع نشاطها عندما ترتفع الجرعات.

كلمات مفتاحية: آفات حشرية، تخزين، ذُرة، رمل سيليزي، لوبيا، نشاط مبيد حشري

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