Comparative Lethality of Rice Husk Ash and a Diatomaceous Eartht Adults of Four Storage Beetles

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Abstract

Lethality of rice husk ash (RHA) and a diatomaceous earth (SilicoSec) (DE) to adults of *Sitophilus zeamais*, *S. granarius*, *Lasioderma serricorne* and *Callosobruchus maculatus* was investigated under controlled conditions of 25 ± 2° C and 60 ± 3% relative humidity. Each product was tested at 0.05 g to 0.5 g/20 g of grain respectively in glass Petri dishes against 20 adults of each beetle. Adult mortality was observed up to 10 days post treatment. RHA/DE mixtures (1:1, 3:1 and 1:3 ratios) were also tested at 2% of grain weight. Additionally, RHA and DE were tested at low dosages (0.01 g to 0.04 g/20 g) against adults of *C. maculatus* alone. The DE generally produced significantly higher mortality of all the adult storage beetles and at earlier observation times, than RHA at the lower dosages (< 0.2 g). Adult mortality produced by RHA and DE in *S. zeamais* and *S. granarius* increased with increase in dosage from 0.05 g to 0.5 g. The RHA/DE mixtures generally produced similar mortality of all the adult storage beetles irrespective of post-treatment exposure time. The *S. zeamais* and *S. granarius* were generally more tolerant to the DE and RHA treatments than *L. serricorne* and *C. maculatus*. Percentage mortality of *C. maculatus* adults when DE was applied at low dosages (0.01 g to 0.04 g) was generally higher than RHA applied at similar dosages, up to 3 days-post treatment. All treatments produced 100% mortality of *C. maculatus* adults 4 days-post treatment. The data further confirm the efficacy of DE and RHA as insecticidal dusts at the dosage rate of 0.5 g or more per kg of grain.

Keywords: Rice Husk Ash; diatomaceous earth (Silico Sec); lethality; storage beetles

1. Introduction

In developing countries losses caused by insect pests may reach 6.5% or more of stored grain (Raju, 1984), making control imperative. Control of these insects by synthetic chemical insecticides is effective, but has several drawbacks such as increasing costs, inconsistent supplies and hazards to man and the environment (Ofuya, 2003). Inert dusts such as ash and diatomaceous earths may be suitable alternatives to contact insecticides from the point of view of resource poor farmers (Stathers et al., 2008). Rice husk ash appears to be especially effective in the control of stored products insect pests (Tee, 1981; Ofuya and Adler, 2014). Diatomaceous earth is an inert dust of almost pure amorphous silicon dioxide and made up of fossilized diatoms; and has been variously applied for the management of stored-product pests with good results (Shah and Khan, 2014; Perisic, 2018). The main ingredient of rice husk ash is silica (SiO_2), accounting for more than 90% of the total content, and therefore similar in composition as diatomaceous earth. However, direct comparison of any diatomaceous earth and rice husk ash in stored products protection against insect infestation has scarcely been reported. This paper reports the results of a study comparing the lethality of rice husk ash and a diatomaceous earth, Silico Sec to adults of four storage beetles namely *Sitophilus zeamais* Mots. *S. granarius* L., *Lasioderma serricorne* F. and *Callosobruchus maculatus* F.

2. Materials and Methods

The study was carried out at the Federal Research Centre for Cultivated Plants, Institute of Ecological Chemistry, Plant Analysis and Stored Product Protection, Berlin, Germany under controlled conditions of 25 ± 2° C and 60 ± 3% relative humidity.

Insects

The storage insects tested in the study are the cowpea seed beetle, *Callosobruchus maculatus* Fabricius*,* the maize weevil, *Sitophilus zeamais* Mots., the granary weevil, *S. granarius* L. and the cigarette beetle, *Lasioderma serricorne* Fabricius. Their cultures are maintained at Institute of

Ecological Chemistry, Plant Analysis and Stored Product Protection, Berlin, Germany using standard procedures (e.g. Tofel *et al*., 2015). The *C. maculatus* was tested using blackeye cowpea whilst *S. zeamais*, *S. granarius* and *L. serricorne* were tested on yellow maize.

Paddy Husk Ash (RHA)

Paddy husk was obtained from a processing mill in Emure in Ekiti State, Nigeria (7.4500° N, 5.4667° E) and rice variety was Igbemo local grown by communities around the metropolis. Paddy husk was first pulverized in an electric blender into coarse powder which was thereafter converted to ash material in electric oven at 550° C for three hours. The husk ash was pulverized in a laboratory mill into a fine powder with particle size of ≤ 150 µm using a British standard sieve (Ofuya and Dawodu, 2002). The ash powder (approximately 100 g) was then put in a plastic container with tight fitted lid.

Diatomaceous Earth (DE)

The diatomaceous earth (DE) used was SilicoSec, a natural silica powder obtained from processed fossilized diatoms. It is composed of 96% amorphous SiO_2 with particle size between 13 µm to 15 µm (Erb-Brinkmann, 2000).

Effect of high dosages of RHA and DE on mortality of adult beetles

Twenty unsexed adults of *C. maculatus* (< 2 days old), *L. serricorne* (< 1 week old), *S. zeamais* (< 2 weeks old) and *S. granarius* (< 2 weeks old) were separately dusted by shaking with either rice husk ash powder (RHA) or SilicoSec (DE) in clear glass Petri dishes (9.0 cm diameter) containing 20 g of cowpea seeds for *C. maculatus* and maize grain for the other beetle species. Each product was tested 0.05, 0.1, 0.2, 0.3, 0.4 and 0.5 g respectively. There was a control treatment with neither RHA nor DE. Adult mortality was observed daily for up to 10 days. The experiment was replicated three times.

Effect of combining RHA and DE on mortality of adult beetles

Twenty unsexed adults of *C maculatus* (< 2 days old), *L. serricorne* (< 1 week old), *S. zeamais* (< 2 weeks old) and *S. granarius* (< 2 weeks old) were separately dusted by shaking with mixtures of RHA and DE in three ratios (1:1, 3:1 and 1:3) in clear glass Petri dishes (9.0 cm diameter) containing 20 g of cowpea seeds for *C. maculatus* and maize grain for the other beetle species. Each mixture was tested at 0.4 g. There was a control treatment with no protectant. Adult mortality was observed daily for up to 10 days. Each treatment was replicated three times.

Effect of low dosages of RHA and DE on mortality of *C. maculatus* adults

Twenty unsexed adults of *C maculatus* (< 2 days old) was dusted by shaking with either rice husk ash powder (RHA) or SilicoSec (DE) in clear glass Petri dishes (9.0 cm diameter) containing 20 g of cowpea seeds. Each product was tested 0.01, 0.02, 0.03 and 0.04 g respectively. There was a control treatment with neither RHA nor DE. Adult mortality was observed daily for up to four days and each treatment was replicated three times

Data analysis

Data were analyzed using the SigmaStat® 3.5 software (Systat Software GmbH, Germany). Mortality data, where necessary, were corrected as recommended by Abbott (1925). Percentage data were arcsine transformed and subjected to one-way analysis of variance (ANOVA. Where the ANOVA indicated significant difference between treatments, least significant difference (LSD) method was used to separate the means at 5% level of probability.

3. Results

Three-days post treatment *S. zeamais* and *S. granarius* suffered higher mortality in DE treated seeds than in the RHA treated seeds with each dosage except with 0.5 g of ash that produced a higher kill of *S. zeamais* than the DE counterpart (Table 1). Five-days post treatment mortality of *S. zeamais* was generally similar to RHA and DE treatments, but DE treatments produced significantly higher kill of *S. granarius* with the 0.05 g and 0.1 dosages in comparison with the RHA counterparts. The trend in adult mortality observed 7 days post treatment was similar to that recorded 5 days post treatment. Ten-days post treatment mortality of *S. zeamais* was generally similar with RHA and DE treatments, but DE treatments produced significantly higher kill of *S. granarius* with the 0.05 g, 0.1 and 0.2 dosages in comparison with the RHA counterparts. Both RHA and DE produced higher adult mortality in *S. zeamais* and *S. granarius* with increase in dosage from 0.05 g to 0.5 g.

For 1-day post treatment all the DE dosages (0.05 g to 0.5 g) produced 100% mortality in adults of *L. serricorne* and *C. maculatus* which was significantly higher than mortality produced by similar dosages of RHA except 0.4 g and 0.5 g.

for *L. serricorne* and 0.3 g, 0.4 g and 0.5 g for C. *maculatus* (Table 2). For 2-days post treatment the DE dosages also produced 100% mortality in adults of *L. serricorne* and *C. maculatus* which was significantly higher than mortality produced by similar dosages of RHA except 0.3 g, 0.4 g and 0.5 g for both beetle species. Similarly, for 3-days post treatment all the treatments produced 100% mortality in *L. serricorne* and *C. maculatus* except in the case of *C. maculatus* exposed to 0.05 g RHA where 81.7% mortality was recorded.

Mean % mortality of *S. zeamais* and *S. granarius* was not significantly different irrespective of the ratio of mixing RHA and DE (1:1, 3:1 or 1:3) for use against these insects, 3-days post treatment except with the 3:1 ratio against *S. granarius* where 16.7% mortality was recorded (Table 3). At 5-days post treatment the RHA/DE (3:1) produced significantly the highest of 76.7% of S. *granarius*. A similar trend was observed at 7 and 10-days post treatment.

The 1-day post treatment the RHA/DE mixtures produced similar mortality of *L. serricorne* (ranging from 23.3% to 30.0%) which was significantly lower than mortality produced by the same mixtures in *C. maculatus* (ranging from 60.0% to 75.0%) (Table 4). A similar trend was observed at 2 and 3-days post treatment. At 5-days post treatment, all the RHA/DE mixtures produced 100% mortality in both *L. serricorne* and *C. maculatus*. Mean % mortality of *C. maculatus* adults when DE was applied at low dosages (0.01 g to 0.04 g) was significantly higher than RHA applied at similar dosages during 1, 2 and 3-days post treatment except RHA applied at 0.04 g which produced 100% mortality 3-days post treatment as in DE treatments (Table 5). All the treatments produced 100% mortality of *C. maculatus* adults at 4-days post treatment. For the RHA treatments, mortality increased significantly with increase in dosage except on the 4th day post treatment.

Table 1. Mortality of adults of *S. zeamais* and *S. granarius* in RHA and DE applied at different dosages

Protectant/ Insect	Dosage (g/20 g of grain)	Mean % mortality in: 3 days	5 days	7 days	10 days
RHA/*S. zeamais*	0.05	13.3 ± 3.33ab	28.3 ± 10.93abc	41.7 ± 4.41ab	61.7 ± 7.27bc
	0.1	30.0 ± 2.89cd	46.6 ± 1.67cdef	65.0 ± 2.89cdefg	86.7 ± 1.67efg
	0.2	36.7 ± 1.67cd	65.0 ± 7.64fghi	66.7 ± 4.41defgh	96.7 ± 1.67g
	0.3	43.3 ± 8.33def	66.7 ± 10.14fghi	76.7 ± 10.14efghij	93.3 ± 4.41fg
	0.4	63.3 ± 1.67ghi	73.3 ± 1.67ghi	100.0 ± 0.00k	100.00 ± 0.00g
	0.5	76.7 ± 10.93ij	95.0 ± 5.00j	100.0 ± 0.00k	100.00 ± 0.00g
DE/*S. zeamais*	0.05	21.7 ± 1.67bc	30.0 ± 5.77bcd	51.7 ± 4.41bcd	70.0 ± 2.89cd
	0.1	35.0 ± 2.89cd	51.7 ± 3.33defg	70.0 ± 2.89defghi	95.0 ± 2.89fg
	0.2	41.7 ± 8.33def	63.3 ± 1.67fghi	76.7 ± 4.41efghij	96.7 ± 3.33g
	0.3	70.0 ± 2.89ghi	75.0 ± 2.89hij	86.7 ± 4.41ghijk	100.0 ± 0.00g
	0.4	76.7 ± 1.67ij	81.7 ± 3.33ij	100.0 ± 0.00k	100.00 ± 0.00g
	0.5	90.0 ± 2.89j	98.3 ± 1.67j	100.0 ± 0.00k	100.00 ± 0.00g
RHA/*S. granarius*	0.05	0.0 ± 0.00a	6.7 ± 1.67a	21.7 ± 6.01a	26.7 ± 3.33a
	0.1	10.0 ± 2.89ab	15.0 ± 2.89ab	43.3 ± 13.02abc	48.3 ± 10.14b
	0.2	21.7 ± 6.67b	40.0 ± 5.00cde	55.0 ± 2.89bcde	88.3 ± 3.33fg
	0.3	36.7 ± 8.82cd	50.0 ± 5.77cdefg	76.7 ± 6.01efghij	90.0 ± 2.89fg
	0.4	55.0 ± 2.89efg	71.7 ± 4.41ghi	88.3 ± 4.41hijk	100.00 ± 0.00g

	0.5	60.0 ± 2.89fgh	68.3 ± 1.67fghi	90.0 ± 2.89ijk	100.00 ± 0.00g
DE/*S. granarius*	0.05	31.7 ± 1.67cd	50.0 ± 2.89cdef	63.3 ± 4.41bcdef	73.3 ± 3.33cde
	0.1	56.7 ± 4.41efgh	68.3 ± 4.41fghi	76.7 ± 3.33efghij	81.7 ± 1.67def
	0.2	30.0 ± 2.89cd	56.7± 1.67efgh	78.3 ± 4.41fghijk	96.7 ± 1.67g
	0.3	56.7 ± 4.41efgh	68.3 ± 4.41fghi	86.7 ± 1.67ghijk	100.0 ± 0.00g
	0.4	71.7 ± 1.67hi	76.7 ± 3.33hij	91.7 ± 1.67ijk	100.00 ± 0.00g
	0.5	68.3 ± 7.27ghi	75.0 ± 5.00hij	93.3 ± 1.67jk	100.00 ± 0.00g
LSD 0.001		15.39	21.71	21.94	14.91

Along each column means bearing similar letters are not significantly different

4. Discussion

The results of this study showed that DE was generally more toxic to *S. zeamais* and *S. granarius* than RHA. DE produced 100% mortality in adults of these two beetles 10 days post-treatment at the dosage of 0.3 g or more per 20 g of grain whereas it required 0.4 g or more of RHA to achieve the same level of mortality. Similarly, the DE was generally more toxic to *L. serricorne* and *C. maculatus* than RHA. It was further observed that mortality of *C. maculatus* adults when DE was applied at low dosages (0.01 g to 0.04 g) was generally higher than RHA applied at similar dosages. Demissie et al. (2008) reported that diatomaceous earth was superior to wood ash in the control of *S. zeamais*. Our results may support the assertion by Shah and Khan (2014) that DE is probably one of the most efficacious natural dusts used as an insecticide. Sadeghi et al. (2012), however, did not record overwhelming superiority in lethality of Sayan®, a DE, to adults of six stored products insects including *S. zeamais*, *L. serricorne* and *C. maculatus* when compared with bran and sawdust. The DE used in this study is SilicoSec, composed of 96% amorphous SiO_2 with particle size between 13 µm to 15 µm (Erb-Brinkmann, 2000). Sayan® DE formulation contains 92% SiO_2 and an average particle size of 50 µm (Sadeghi et al., 2012). Differences in chemical and physical properties of insecticidal dusts can influence their efficacies (Dawodu and Ofuya, 2002; Olotuah et al., 2010; Shah and Khan, 2014).

Species variation in susceptibility to DE and RHA treatment was clearly observable in this study. Adults of *S. zeamais* and *S. granarius* were less susceptible to DE and RHA than those of *L. serricorne* and *C. maculatus*. For example, irrespective of dosage DE killed all introduced *L. serricorne* and *C. maculatus* adults within 1 day post treatment whereas a DE dosage of 0.4 g or more per 20 g of grain required 7 days to kill all introduced *S. granarius* and *S. zeamais* adults. Also, whilst 0.4 g dosage of RHA killed all introduced *L. serricorne* and *C. maculatus* adults within 2 days post treatment, the same dosage of RHA required 10 days to kill all introduced *S. granarius* and *S. zeamais* adults. Observations that stored products insects show a wide range of susceptibility to inert dusts have been reported by some other workers (Athanassiou et al., 2005; Sadeghi et al., 2012; Doumbia et al., 2014). Differences in susceptibility to inert dusts by insects could be due to size, quantitative or qualitative differences in cuticular lipids, differences in agility through grain, behavioural responses to the dusts or resistance to desiccation (Shah and Khan, 2014).

Ofuya and Adler (2015) observed that DE could be mixed with insecticidal plant powders without jeopardizing its lethality against four different adult storage beetles. Indeed mixing with DE was thought to have putatively increased the lethality of *Piper guineense* Schum & Thonn dry fruit and rice husk powders to the adult beetles. Ofuya et al. (2015) reached a similar conclusion. However, the results of this study indicate that there may be no advantage in mixing DE and RHA for stored products protection against insect infestation in terms of adult mortality. The DE and RHA may not have been physically homogeneous partly due to inherent differences in particle size. RHA has been reported to contain a large amount of needle-like particles presumably derived from setae covering the outer surface of the rice husk which may putatively trigger a physical reaction on the integument of insects that eventually results in their

death (Ofuya and Adler, 2014). It is hereby hypothesized that DE may have obliterated the activity of these needle-like particles in the RHA/DE mixtures, thus decreasing the ability to cause death of the insects.

Overall, data had been provided that further confirm the efficacy of DE and RHA as insecticidal dusts at the dosage rate of 0.5 g or more per kg of grain. The DE was observed to be generally more lethal to the beetles than RHA. *S. zeamais* and *S. granarius* were generally more tolerant to the DE and RHA treatments than *L. serricorne* and *C. maculatus*. For *C. maculatus* there is the possibility of achieving good control at lower dosage rate of DE and RHA of less than 0.5 g per kg of grain.

Table 2. Mortality of adults of *L. serricorne and C. maculatus* in RHA and DE applied at different dosages

Protectant/Insect	**Dosage (g/20 g of grain**	**Mean % mortality (± SE) in:**		
		1 day	**2 days**	**3 days**
RHA/*L. serricorne*	0.05	25.0 ± 2.89b	80.0 ± 2.89b	100.0 ± 0.00b
	0.1	31.7 ± 4.41b	83.3 ± 4.41b	100.0 ± 0.00b
	0.2	68.3 ± 4.41cd	93.3 ± 1.67c	100.0 ± 0.00b
	0.3	75.0 ± 2.89de	100.0 ± 0.00d	100.0 ± 0.00b
	0.4	93.3 ± 1.67fg	100.0 ± 0.00d	100.0 ± 0.00b
	0.5	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
DE/*L. seericorne*	0.05	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
	0.1	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
	0.2	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
	0.3	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
	0.4	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
	0.5	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
RHA/*C. maculatus*	0.05	10.0 ± 5.77a	55.0 ± 2.89a	81.7 ± 4.41a
	0.1	33.3 ± 8.82b	81.7 ± 1.67b	100.0 ± 0.00b
	0.2	33.3 ± 4.41b	90.0 ± 2.89c	100.0 ± 0.00b
	0.3	55.0 ± 5.77c	100.0 ± 0.00d	100.0 ± 0.00b
	0.4	83.3 ± 1.67ef	100.0 ± 0.00d	100.0 ± 0.00b
	0.5	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
DE/*C. maculatus*	0.05	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
	0.1	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
	0.2	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
	0.3	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
	0.4	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
	0.5	100.0 ± 0.00g	100.0 ± 0.00d	100.0 ± 0.00b
LSD 0.001		13.99	6.60	4.11

Along each column means bearing similar letters are not significantly different

Table 3. Mortality of adults of *S. zeamais* and *S. granarius* in RHA and DE in mixed formulations but applied in a single dosage of 2% of protected grain weight

Insect	**Ratio (RHA:DE)**	**Mean % mortality (± SE) in:**			
		3 days	**5 days**	**7 days**	**10 days**
S. zeamais					
	1:1	40.0 ± 7.64b	48.3 ± 10.14ab	63.3 ± 6.00a	76.7 ± 4.41a
	3:1	46.6 ± 4.41b	56.7 ± 3.33b	75.0 ± 2.89b	85.0 ± 2.89ab
	1:3	43.3 ± 8.82b	48.3 ± 8.33b	56.7 ± 4.41a	76.7 ± 4.41a
S. granarius					
	1:1	31.7 ± 7.27ab	50.0 ± 2.89ab	78.3 ± 1.67b	90.0 ± 2.89b
	3:1	16.7 ± 3.33a	38.3 ± 4.41a	68.3 ± 4.41ab	83.3 ± 3.33ab
	1:3	43.3 ± 3.33b	76.7 ± 3.33c	90.0 ± 2.89c	100.0 ± 0.00c
LSD 0.05		15.62	15.34	10.00	8.40

Along each column means bearing similar letters are not significantly different

Table 4. Mortality of adults of *L. serricorne* and *C. maculatus* in RHA and DE in mixed formulations but applied in a single dosage of 2% of protected grain weight

Insect	**Ratio (RHA:DE)**	**Mean % mortality (± SE) in:**			
		1 day	**2 days**	**3 days**	**5 days**

L. serricorne					
	1:1	26.7 ± 7.27a	50.0 ± 2.89ab	75.0 ± 2.89a	100.0 ± 0.00
	3:1	23.3 ± 6.00a	45.0 ± 5.00a	75.0 ± 2.89a	100.0 ± 0.00
	1:3	30.0 ± 5.77a	55.0 ± 2.89b	83.3 ± 4.41a	100.0 ± 0.00
C. maculatus					
	1:1	66.0 ± 3.33bc	90.0 ± 2.89c	100.0 ± 0.00b	100.0 ± 0.00
	3:1	60.0 ± 5.77b	85.0 ± 2.89c	100.0 ± 0.00b	100.0 ± 0.00
	1:3	75.0 ± 2.89c	93.3 ± 1.67c	100.0 ± 0.00b	100.0 ± 0.00
LSD 0.05		13.61	8.04	7.47	Ns

Along each column means bearing similar letters are not significantly different

Table 5. Mortality of adults of *C. maculatus* in RHA and DE applied at different low dosages

Protectant	**Dosage (g/20 g of grain**	**Mean % mortality (± SE) in: 1 day**	**2 days**	**3 days**	**4 days**
DE					
	0.01	86.7 ± 3.33e	96.7 ± 3.33e	100.0 ± 0.00c	100.0 ± 0.00
	0.02	100.0 ± 0.00f	100.0 ± 0.00e	100.0 ± 0.00c	100.0 ± 0.00
	0.03	100.0 ± 0.00f	100.0 ± 0.00e	100.0 ± 0.00c	100.0 ± 0.00
	0.04	100.0 ± 0.00f	100.0 ± 0.00e	100.0 ± 0.00c	100.0 ± 0.00
RHA					
	0.01	6.7 ± 1.67a	35.0 ± 2.89a	83.3 ± 4.41a	100.0 ± 0.00
	0.02	15.0 ± 2.89b	50.0 ± 2.89b	81.7 ± 4.41a	100.0 ± 0.00
	0.03	35.0 ± 2.89c	71.7 ± 1.67c	93.3 ± 1.67b	100.0 ± 0.00
	0.04	41.7 ± 3.33d	83.3 ± 4.41d	100.0 ± 0.00c	100.0 ± 0.00
LSD 0.05		5.64	6.17	5.64	Ns

Along each column means bearing similar letters are not significantly different

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Effects of different inert dusts on *Sitophilus oryzae* and *Plodia interpunctella* during contact exposure

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Abstract

The use of natural inert dusts against storage insect pests is increasing recently, as an alternative to conventional insecticides. Laboratory study was carried out to evaluate the contact effect of three inert dusts, diatomaceous earth (DE), kaoline (KA) and vermiculite (VE), at rates 5, 7.5, 10, 15 and 20 gm^{-2}, against adults of *Sitophilus oryzae* (L.) and larvae of *Plodia interpunctella* (Hubner). Insect mortality was evaluated 1, 2, 3 and 7 days after the exposure. Insect mortality varied depending on the species, concentrations and exposure periods. The DE and KA caused 86.7-98% mortality of *S. oryzae* after 2 days of exposure at the highest rates, while at 5 and 7.5 gm^{-2}, 100% mortality was achieved only after 7 days. The highest rates of inert dusts caused 42-50% (DE) and 60-75% (KA) mortality of *P. interpunctella* larvae only after 7days. The mortality of moths increased gradually with the concentration and 100% was achieved 3 days after the contact with DE and KA (10, 15 and 20 g m^{-2}). However, inert dusts induced faster pupation of *P. interpunctella*, while adult emergence was reduced and adults had smaller body-sizes, compared to control. The VE caused relatively low mortalities (7-11% of *S. oryzae* adults and 5-8% of *P. interpunctella* larvae) at all tested rates during the entire experiment. Our results have shown good insecticidal effect of DE and KA against *S. oryzae* and *P. interpunctella* at 10, 15 and 20 gm^{-2}. These products could therefore be used by small-scale farmers to protect stored grains against insect pest infestation.

Key words: Inert dusts, *Sitophilus oryzae, Plodia interpunctella*, contact exposure, diatomaceous eartth

Introduction

In recent years, the use of contact insecticides and fumigants for controlling storage pests is under increasing restriction due to the presence of residues in food and development of insect resistance (Collins, 2000; Kljajić and Perić, 2005). These shortcomings have stimulated the need for testing and evaluation of non-toxic methods that can replace conventional insecticides in stored grains (Arthur, 1996). Recently, physical control methods, like the use of inert dusts, have become prominent (Field and Korunić, 2002). These materials are classified into different groups depending on their composition and particle size and include materials such as diatomaceous earth, silicophosphate, rock phosphate, sand, kaolinite, clay etc. (Golob, 1997). There is a growing interest especially in desiccant or absorptive dusts, among which, diatomaceous earth is the most widely used in practice worldwide (Golob, 1997; Korunić, 1998a; Subramanyam and Roesli, 2000) and in commercial storages in the developed world. On the other hand, non-silica dusts and those composed of coarse grain silicates, such as kaoline and sand, have been used traditionally as grain protectants by small-