Impact of *Lavandula officinalis*, inert dusts and their formulations on *Sitophilus oryzae*

Ahmed Mohamed El-Bakry*, Nahed Fawzy Abdel-Aziz, Elham Ahmed Sammour

(*Pests and Plant Protection Department, National Research Centre, El Buhouth St., Dokki-Cairo, Egypt Postal Code 12622*)

Abstract: The volatile oil (*Lavandula officinalis* L.) and the inorganic compounds (inert dusts), aluminum oxide, kaolin and silicon dioxide were screened individually and in formulations against the rice weevil, *Sitophilus oryzae*. Aluminum oxide was the most potent with LC_{50} value of 0.65 mg cm^{-2}, followed by silicon dioxide with LC_{50} value of 0.96 mg cm^{-2}, while, kaolin gave LC_{50} value of 9.29 mg cm^{-2}. The cumulative mortality (0-50, 50-100, 100-150, 150-200, 200-250, 250-300 days) responses at exposure times of *L. officinalis* and the inert dusts as well as the inert dust formulations at LC_{50} concentrations against *S. oryzae* were investigated. Moreover, the number of the offspring after 50 days of each lifetime period was developed. *L. officinalis* had a short duration of toxicity, as the efficiency continued only for 2 days from exposure to the compound. Silicon dioxide alone or in formulation was the most powerful, it gave full control of *S. oryzae* adults after 7 days at four (0-50, 50-100, 100-150, 150-200 days) and five (0-50, 50-100, 100-150, 150-200, 200-250 days) lifetime periods, respectively, in the same trend, silicon dioxide alone or in formulation possessed 100% reduction of the offspring at five life time periods. Moreover, aluminum oxide alone or in formulation gave full control of the insect after 7 days of exposure until three lifetime periods of the compound. Likewise, the compound alone or in formulation, possessed 100% reduction of the offspring at four lifetime periods. The formulations of aluminum oxide and silicon dioxide were more efficient than the compounds treated alone, where the effectiveness increased nearly two times, after 2 days from exposure at first 50 days lifetime period. Likewise, kaolin formulation was more effective than kaolin alone in the same lifetime period.

Keywords: *Lavandula officinalis*, Inert dusts, *Sitophilus oryzae*, Cumulative mortality

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1 Introduction

Cereals play a very important role as sources of nutrients. Cereals are considered as a paramount source of energy, carbohydrate, protein and fibre, it contains a range of micronutrients like vitamin E, some of the B vitamins, magnesium and zinc (McKevith, 2004). Cereals play a very important role in developing countries, but due to the onslaught of pests, a loss of 20%-60% has been reported (Arthur and Throne, 2003).

Stored-grain insects cause economic reductions in weight and nutritional value; also, they cause deterioration and contamination from the presence of insects, resulting in downgrading of grain and market value on account of insect parts, odors and molds. Among them, rice weevil, *Sitophilus Oryzae* (L.), that is one of the most destructive insect, which cause severe economic loss. However, the grain industry wants to reduce utilization of pesticides due to insecticide deregulation, resistant populations and consumer solicitude over insecticide residues. Therefore, there is an urgent need for safer methods of pest management (Fields, 1998; Rajashekar and Shivanandappa, 2010; Abdel-Aziz et al., 2015; Salem et al., 2016).

Inert dusts possess various industrial and agricultural uses, some used as insecticide dust diluents and carriers (Ebeling, 1971). Inert dusts are used to control stored products (Mel'zina et al., 1982; Rajasri et al., 2012;

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*** Corresponding author: Ahmed Mohamed El-Bakry,** Researcher, Pests and Plant Protection Department, National Research Centre, El Buhouth St., Dokki-Cairo, Egypt Postal Code 12622. Tel: +202-33371362, Fax: +202-33370931, Email: ah_albakry@hotmail.com.

Mahgoub and Zewar, 2014).

Unlike conventional contact insecticides, inert dusts make the action via their physical properties and therefore, they are generally slower acting (Maceljski and Korunic, 1972). Insect mortality is induced foremost resulting from desiccation: water loss is a consequence of the destruction of the cuticle.

A valid alternative to the residual insecticides of stored grain protection is inert dusts, which mixed into the grain as previously used by the Egyptians, the Chinese and the Romans (Quarles and Winn, 1996).

The aim of this study is to evaluate the efficiency of some inert dusts and their cumulative mortality as well as the formulations of these inert dusts with *L. officinalis* against the rice weevil, *S. oryzae* (L.). In addition, evaluation the effect of the tested compounds on the number of the offspring of *S. oryzae* after 50 days of each (six) lifetime periods.

2 Materials and methods

Plant materials: *L. officinalis* L. (leaves) was collected during the flowering stage.

Preparation of the essential oil: The plant material was dried at room temperature (26°C±1°C) for five days. Essential oil was extracted by hydro-distillation in a Clevenger-type apparatus for 5 h. The oil was dried over anhydrous sodium sulfate, and stored at 4°C until used for biological activities.

Test insects: Cultures of the rice weevil, *S. oryzae* were maintained in our laboratory without exposure to insecticides and reared on sterilized whole wheat. Insect rearing at 26°C±1°C and 65%±5% R.H. and a 12:12 light: dark photoperiod. Adults used in toxicity studies were 7 days-old.

Contact toxicity assay: From our preliminary studies. *L. officinalis* L. was the most effective in controlling *S. oryzae* (El-Bakry et al., 2016)*;* therefore, it was candidate to mix with the inert dusts of aluminum oxide, kaolin and silicon dioxide of LC_{50} values.

2.1. Efficiency of *L. officinalis*:

The cumulative mortality of *L. officinalis* was determined by direct contact application. The LC_{50} concentration of *L. officinalis* (0.065 mg cm^{-2}) was prepared using acetone as a solvent. Aliquots of 1 ml was applied on the bottom of a glass Petri dish (7 cm diameter). After evaporation of the solvent for 2 min, one g of wheat grains and 10 adults of the insect were placed in each Petri dish. The cumulative mortality was recorded after 2, 7, 14 and 21 days from exposure to the tested compound. The dead insects were removed 2, 7 and 14 days later, then after 21 days, all the insects were removed. The number of the offspring of *S. oryzae* was recorded after 50 days, then the offspring of *S. oryzae* and wheat grains were removed. Another wheat grains and adult insects were placed in the previous treated Petri dishes in order to investigate the persistence of the tested compounds. Five replicates of treated and untreated wheat were used.

2.2 Efficiency of inert dusts

The insecticidal activity of aluminum oxide, kaolin and silicon dioxide were determined by direct contact application. A series of concentrations (mg cm^{-2}) of the inert dusts were prepared in glass Petri dishes (7 cm diameter). Five replicates were carried out for each treatment. The mortality percentages were recorded after 48 hours of treatment.

The LC_{50} concentrations of aluminum oxide, kaolin and silicon dioxide were placed in glass Petri dishes (7 cm diameter) and mixed with 1 g of wheat grains and 10 adults of the insect. The cumulative mortality was determined as previously mentioned.

2.3 Efficiency of inert dust formulations

The LC_{50} concentrations of each *L. officinalis* (0.065 mg cm^{-2}) and inert dusts were mixed individually by adding 1 ml acetone. After evaporation of the solvent, the mixture was placed in a glass Petri dish (7 cm diameter) and mixed with 1 g of wheat grains and 10 adults of the insect. The cumulative mortality and the number of the offspring were recorded.

Statistical analysis: Data were subjected to one-way analysis of variance followed by Student–Newman–Keuls test; Cohort software Inc. Costat, 2004 to determine significant differences among mean values at the probability levels of 0.05. The concentration–mortality data were subjected to Probit analysis to obtain the LC_{50} values (Finney, 1971) using the SPSS 21.0 software program (SPSS, 2012). The values of LC_{50} were considered significantly different, if the 95% confidence limits did not overlap.

3 Results and discussion

The insecticidal potential of the inert dusts was evaluated against *S. oryzae*, the LC_{50} values (mg cm^{-2}), 95% confidence limits (mg cm^{-2}) and slopes of regression lines of the inert dusts, aluminum oxide, kaolin and silicon dioxide against the tested insect are shown in Table 1. The results revealed that, aluminum oxide was the most effective with LC_{50} value of 0.65 mg cm^{-2}, followed by silicon dioxide with LC_{50} value of 0.96 mg cm^{-2}. Kaolin was the least effective with LC_{50} value of 9.29 mg cm^{-2}.

The cumulative mortality responses to exposure time of *L. officinalis* and the inert dusts at LC_{50} concentrations against *S. oryzae* is recorded in Tables 2-4. In the lifetime of 50 days period of the tested compounds, the cumulative mortality of *L. officinalis* was 46.67% after 2 and 7 days from exposure to the tested compounds, it increased to 50% after 14 and 21 days. The progeny reduction was 54.3% after 50 days of exposure. Furthermore, aluminum oxide and silicon dioxide gave 53.3% and 50% mortality, respectively, after 2 days from exposure, while, they totally controlled the adults (the cumulative mortality=100%) after 7 days. Likewise, the reduction of progeny was 100%. On the other hand, kaolin did not completely control the adult insects, even after 21 days of the exposure to the treated wheat (the cumulative mortality=66.7%) and it reduced the offspring by 75.7%. Concerning, the period of 50-100 days lifetime of compounds, *L. officinalis* did not have any efficiency, where the cumulative mortality was 13.3%, even after 21 days of exposure and the reduction of the offspring was zero. On the other hand, the mortality of aluminum oxide and silicon dioxide were 53.3% and 46.7%, respectively, after 2 days from exposure to the treated wheat. They achieved full control after 7 d; also, the full reduction of the progeny was obtained. Kaolin gave moderate efficiency (the cumulative mortality = 43.3%, 73.3% and 80% after 7, 14 and 21 days from exposure, respectively), while the reduction of progeny was 73.9%. At the period of 100-150 days lifetime of compounds, aluminum oxide and silicon dioxide continue possessed full control of *S. oryzae* adults after 7 days and 100% reduction of the offspring. Moreover, Kaolin has the same effect of the previous lifetime period (the cumulative mortality = 83.33% after 21 days of exposure and the offspring reduction was 76.67%).

Table 1 Contact efficiency of the inert dusts against *Sitophilus oryzae*

Inert dusts	LC_{50}, mg cm^{-2}	95% Confidence limits, mg cm^{-2}		Slope±SE[b]	Intercept±SE[c]	$(\chi^2)^d$
		Lower	Upper			
Aluminum oxide	0.65	0.48	0.85	1.35 ± 0.06	0.25 ± 0.04	67.71
Kaolin	9.29	7.41	11.79	1.5 ± 0.08	-1.45 ± 0.08	72.83
Silicon dioxide	0.96	0.86	1.06	5.63 ± 0.32	0.1 ± 0.04	64.5

Note: [a] Concentration causing 50% mortality after 48 h of treatment. [b] Slope of concentration mortality regression line. [c] Intercept of regression line. [d] Chi square value.

Table 2 Contact efficiency of *L. officinalis* and the inert dusts at LC_{50} concentrations against *Sitophilus oryzae* after different exposure periods (0-100 days lifetime of compounds)

Compounds	Lifetime of compounds (50 days)					%R[1]	Lifetime of compounds (50-100 days)					%R
	Cumulative mortality (%) after days				The offspring after 50 days of exposure		Cumulative mortality (%) after days				The offspring after 50 days of exposure	
	2 d	7 d	14 d	21 d	50 d		2 d	7 d	14 d	21 d	50 d	
L. officinalis	46.7[a3]	46.7[c]	50[c]	50[c]	42.7[b]	54.3[c]	6.67[c]	13.3[c]	13.3[c]	13.3[c]	95.7[a]	0[c]
Aluminum oxide	53.3[a]	100[a]	100[a]	100[a]	0[d]	100[a]	53.3[a]	100[a]	100[a]	100[a]	0[c]	100[a]
Kaolin	40[b]	63.3[b]	66.7[b]	66.7[b]	22.7[c]	75.7[b]	16.7[b]	43.3[b]	73.3[b]	80[b]	24.3[b]	73.9[b]
Silicon dioxide	50[a]	100[a]	100[a]	100[a]	0[d]	100[a]	46.7[a]	100[a]	100[a]	100[a]	0[c]	100[a]
Cont.	0[c]	0[d]	6.67[d]	10[d]	93.3[a]	0[d]	0[c]	10[c]	10[c]	13.3[c]	93.3[a]	0[c]
$L.S.D_{0.05}$[2]	6.43	6.43	7.29	4.86	10.26	5.66	9.72	11.13	13.96	10.31	7.56	9.63

Note: [1] Percent of insect reduction compared with the control treatment. [2] least significant difference at 0.05 level of probability. [3] Means followed by the same letter in a column are not significantly different at 5% level of probability (Duncan Test).

Table 3 Contact efficiency of *L. officinalis* and the inert dusts at LC_{50} concentrations against *Sitophilus oryzae* after different exposure periods (100-200 days lifetime of compounds)

Compounds	Lifetime of compounds (100-150 days)						Lifetime of compounds (150-200 days)					
	Cumulative mortality (%) after days				The offspring after 50 days of exposure	%R[1]	Cumulative mortality (%) after days				The offspring after 50 days of exposure	%R
	2 d	7 d	14 d	21 d	50 d		2 d	7 d	14 d	21 d	50 d	
L. officinalis	0^{b3}	6.67^{c}	6.67^{c}	10^{c}	108.33^{a}	1.52^{c}	6.67^{b}	6.67^{d}	10^{d}	13.33^{c}	115.67^{a}	0.28^{c}
Aluminum oxide	53.33^{a}	100^{a}	100^{a}	100^{a}	0^{c}	100^{a}	46.67^{a}	73.33^{b}	83.33^{b}	93.33^{a}	0^{c}	100^{a}
Kaolin	0^{b}	43.33^{b}	60^{b}	83.33^{b}	25.67^{b}	76.67^{b}	36.67^{a}	56.67^{c}	56.67^{c}	56.67^{b}	52^{b}	55.17^{b}
Silicon dioxide	53.33^{a}	100^{a}	100^{a}	100^{a}	0^{c}	100^{a}	50^{a}	100^{a}	100^{a}	100^{a}	0^{c}	100^{a}
Cont.	3.33^{b}	6.67^{c}	6.67^{c}	6.67^{c}	110^{a}	0^{c}	0^{b}	0^{d}	10^{d}	10^{c}	116^{a}	0^{c}
$L.S.D_{0.05}$[2]	8.42	9.09	7.29	6.43	13.76	12.12	13.96	14.98	6.43	6.87	8.78	8.89

Note: [1] Percent of insect reduction compared with the control treatment. [2] least significant difference at 0.05 level of probability. [3] Means followed by the same letter in a column are not significantly different at 5% level of probability (Duncan Test).

Table 4 Contact efficiency of *L. officinalis* and the inert dusts at LC_{50} concentrations against *Sitophilus oryzae* after different exposure periods (200-300 days lifetime of compounds)

Compounds	Lifetime of compounds (200-250 days)						Lifetime of compounds (250-300 days)					
	Cumulative mortality (%) after days				The offspring after 50 days of exposure	%R[1]	Cumulative mortality (%) after days				The offspring after 50 days of exposure	%R
	2 d	7 d	14 d	21 d	50 d		2 d	7 d	14 d	21 d	50 d	
L. officinalis	0^{c}	3.33^{c}	3.33^{c}	6.66^{c}	126^{a}	2.07^{d}	0^{c}	0^{c}	3.33^{c}	3.33^{c}	128^{a}	0^{d}
Aluminum oxide	53.33^{a}	83.33^{a}	93.33^{a}	100^{a}	27.67^{c}	78.49^{b}	26.67^{b}	26.67^{b}	36.67^{b}	36.67^{b}	45^{c}	64^{b}
Kaolin	20^{b}	43.33^{b}	43.33^{b}	66.67^{b}	55^{b}	57.25^{c}	6.66^{c}	6.66^{c}	6.66^{c}	6.66^{c}	70^{b}	44^{c}
Silicon dioxide	53.33^{a}	86.66^{a}	86.66^{a}	100^{a}	0^{d}	100^{a}	53.33^{a}	53.33^{a}	53.33^{a}	63.33^{a}	12^{d}	90.4^{a}
Cont.	0^{c}	0^{c}	3.33^{c}	6.66^{c}	128.67^{a}	0^{d}	0^{c}	3.33^{c}	3.33^{c}	3.33^{c}	125^{a}	0^{d}
$L.S.D_{0.05}$[2]	11.9	10.59	11.4	5.95	6.21	4.05	9.09	10.02	10.31	10.31	4.94	4.24

Note: [1] Percent of insect reduction compared with the control treatment. [2] least significant difference at 0.05 level of probability. [3] Means followed by the same letter in a column are not significantly different at 5% level of probability (Duncan Test).

Silicon dioxide continues to achieve full control after 7 days and 100% reduction of the offspring at the period of 150-200 days lifetime of compounds, while aluminum oxide gave 93.33% cumulative mortality after 21 days of exposure and full reduction of progeny. On the other hand, kaolin gave 56.67% cumulative mortality after 21 days of exposure to treated wheat and 55.17% reduction of the offspring. Concerning, the period of 200-250 lifetime of compounds, both aluminum oxide and silicon dioxide recorded complete control after 21 days, likewise, silicon dioxide gave a complete reduction of the progeny, while aluminum oxide gave 78.49%. Kaolin continues giving a moderate mortality of 66.67% a reduction after 21 days and 57.25% reduction of the offspring.

Otherwise, the cumulative mortality of aluminum oxide and silicon dioxide decreased drastically at the period of 250-300 lifetime of compounds, where the cumulative mortalities were 36.76% and 63.33%, respectively, after 21 days of exposure to the treated wheat, on the other hand, silicon dioxide gave a satisfactory reduction of the progeny of 90.4%, while aluminum oxide recorded 64%. However, the cumulative mortality of kaolin dropped to 6.66% after 21 days, in addition, the reduction of progeny decreased to 44%.

Silicon dioxide was the most efficient, where it possessed full control of *S. oryzae* adults after 7 days at the four given lifetime periods of the tested compounds, moreover, it gave 100% reduction of the offspring at the different lifetime periods. In addition, aluminum oxide possessed a powerful effect toward the insect, as it gave full control of the insect after 7 days of exposure until 100-150 days lifetime period of the compound. Furthermore, it possessed 100% reduction of the offspring at all tested lifetime periods. Kaolin has insufficient control contra *S. oryzae,* which attributed to the low (LC_{50}) applied concentration. Hence, the higher the concentrations the greater the efficiency. On the other hand, the efficiency of *L. officinalis* continued only for

2 days of exposure to the compound. The short residual activity may be due to the temperature and UV light degradation. Our findings are in conformity with Heydarzade and Moravvej (2012) who found that, the biological activity of *Foeniculum vulgare* and *Teucrium polium,* essential oils against *Callosobruchus maculatus* were lost in a relatively short time and did not exceed 30 h. Misra and Pavlostathis (1997) mentioned that the constituents of essential oils are biodegradable, with short half-lives ranging from 30 to 40 h. It is worth mentioning that, the effective insect control in commercial grain stores requires both complete progeny and adult insect eradication.

The cumulative mortality responses to exposure time of the inert dust formulations against *S. oryzae* is clarified in Tables 5-7. The formulation of silicon dioxide achieved complete control of *S. oryzae* adults after 7 days of exposure to treated wheats at 50, 50-100, 100-150, 150-200 and 200-250 days lifetime periods. In addition, the cumulative mortality recorded 73.33% after 21 days at 250-300 lifetime period. Moreover, the formulation possessed 100% reduction of offspring at all different lifetime periods, except the period of 250-300 lifetime, where the reduction of progeny was 91.47%. In the same trend, the formulation of aluminum oxide has promising effect on *S. oryzae* adults, where it gave complete control after 7 days of exposure and full reduction of the offspring at 50, 50-100 and 100-150 days lifetime periods.

The cumulative mortality decreased drastically to 20% after 21 days at 250-300 lifetime period. Likewise, the formulation gave 65.9% reduction of progeny at the same lifetime period. Concerning, kaolin formulation, it achieved compete mortality only after 21 days at 50 days lifetime period, while it possessed 81.21% reduction of the offspring at the same lifetime period.

Table 5 Contact efficiency of inert dust formulations against *Sitophilus oryzae* after different exposure periods (0-100 days lifetime of compounds)

Compounds	LC_{50} Concentrations, mg cm^{-2}	Lifetime of compounds (50 days)						Lifetime of compounds (50-100 days)					
		Cumulative mortality (%) after days				The offspring after 50 days of exposure	%R[1]	Cumulative mortality (%) after days				The offspring after 50 days of exposure	%R
		2 d	7 d	14 d	21 d	50 d		2 d	7 d	14 d	21 d	50 d	
L. officinalis + Aluminum oxide	0.065+0.65	93.33^{a3}	100^{a}	100^{a}	100^{a}	0^{c}	100^{a}	50^{a}	100^{a}	100^{a}	100^{a}	0^{c}	100^{a}
L. officinalis + Kaolin	0.065+9.29	36.67^{b}	56.67^{b}	90^{a}	100^{a}	20.67^{b}	81.21^{b}	13.33^{b}	43.33^{b}	70^{b}	80^{b}	25^{b}	73.21^{b}
L. officinalis + Silicon dioxide	0.065+0.96	93.33^{a}	100^{a}	100^{a}	100^{a}	0^{c}	100^{a}	53.33^{a}	100^{a}	100^{a}	100^{a}	0^{c}	100^{a}
Cont.	–	0^{c}	0^{c}	6.67^{b}	10^{b}	110^{a}	0^{c}	0^{c}	10^{c}	10^{c}	13.33^{c}	93.33^{a}	0^{c}
$L.S.D_{0.05}$[2]		7.44	11.53	12.89	3.1	3.95	1.62	8.8	9.98	12.89	9.98	5.99	2.97

Note: [1] Percent of insect reduction compared with the control treatment. [2] least significant difference at 0.05 level of probability. [3] Means followed by the same letter in a column are not significantly different at 5% level of probability (Duncan Test).

Table 6 Contact efficiency of inert dust formulations against *Sitophilus oryzae* after different exposure periods (100-200 days lifetime of compounds)

Compounds	LC_{50} Concentrations, mg cm^{-2}	Lifetime of compounds (100-150 days)						Lifetime of compounds (150-200 days)					
		Cumulative mortality (%) after days				The offspring after 50 days of exposure	%R[1]	Cumulative mortality (%) after days				The offspring after 50 days of exposure	%R
		2 d	7 d	14 d	21 d	50 d		2 d	7 d	14 d	21 d	50 d	
L. officinalis + Aluminum oxide	0.065+0.648	46.67^{a3}	100^{a}	100^{a}	100^{a}	0^{c}	100^{a}	43.33^{a}	66.67^{b}	80^{b}	86.67^{b}	0^{c}	100^{a}
L. officinalis + Kaolin	0.065+9.29	20^{b}	33.33^{b}	50^{b}	73.33^{b}	26.67^{b}	75.75^{b}	26.67^{b}	40^{c}	50^{c}	50^{c}	49.33^{b}	57.47^{b}
L. officinalis + Silicon dioxide	0.065+0.96	46.67^{a}	100^{a}	100^{a}	100^{a}	0^{c}	100^{a}	50^{a}	100^{a}	100^{a}	100^{a}	0^{c}	100^{a}
Cont.	–	3.33^{c}	6.67^{c}	6.67^{c}	6.67^{c}	110^{a}	0^{c}	0^{c}	0^{d}	10^{d}	10^{d}	116^{a}	0^{c}
$L.S.D_{0.05}$[2]		13.72	11.04	9.98	7.44	11.12	5.08	9.41	5.76	2.51	6.07	5.65	2.73

Note: [1] Percent of insect reduction compared with the control treatment. [2] least significant difference at 0.05 level of probability. [3] Means followed by the same letter in a column are not significantly different at 5% level of probability (Duncan Test).

Table 7 Contact efficiency of inert dust formulations against *Sitophilus oryzae* after different exposure periods (200-300 days lifetime of compounds)

Compounds	LC_{50} Concentrations, mg cm^{-2}	Lifetime of compounds (100-150 days)						Lifetime of compounds (150-200 days)					
		Cumulative mortality (%) after days				The offspring after 50 days of exposure	%R[1]	Cumulative mortality (%) after days				The offspring after 50 days of exposure	%R
		2 d	7 d	14 d	21 d	50 d		2 d	7 d	14 d	21 d	50 d	
L. officinalis + Aluminum oxide	0.065+0.648	43.33^{a3}	76.66^{b}	86.66^{b}	96.66^{a}	21.67^{c}	82.42^{b}	20^{b}	20^{b}	20^{b}	20^{b}	40^{c}	65.9^{b}
L. officinalis + Kaolin	0.065+9.29	16.67^{b}	26.67^{c}	26.67^{c}	33.33^{b}	50.66^{b}	58.92^{c}	3.33^{c}	6.66^{c}	6.66^{c}	6.66^{b}	75.66^{b}	35.51^{c}
L. officinalis + Silicon dioxide	0.065+0.96	53.33^{a}	100^{a}	100^{a}	100^{a}	0^{d}	100^{a}	63.33^{a}	63.33^{a}	63.33^{a}	73.33^{a}	10^{d}	91.47^{a}
Cont.	–	0^{c}	0^{d}	0^{d}	6.67^{c}	123.33^{a}	0^{d}	0^{c}	3.33^{c}	3.33^{c}	3.33^{b}	117.33^{a}	0^{d}
$L.S.D_{0.05}$[2]		11.04	8.8	8.8	7.44	5.36	2.15	12	11.04	11.04	14.89	6.81	4.82

Note: [1] Percent of insect reduction compared with the control treatment. [2] least significant difference at 0.05 level of probability. [3] Means followed by the same letter in a column are not significantly different at 5% level of probability (Duncan Test).

The formulation of silicon dioxide gave the highest efficiency as it gave 100% of mortality after 7 days of exposure and reduction of the progeny at five (50, 50-100, 100-150, 150-200 and 200-250 days) lifetime periods. Likewise, the formulation of aluminum oxide has a remarkable effect on the insect, where it possessed complete mortality until 100-150 days lifetime period, while the complete reduction percentage of the offspring transcend that period to 150-200 days lifetime period.

The effectiveness of inert dusts on stored product insects have been reported as alternative compounds to currently used control agents in several previous studies (Allen, 2001; Goswami et al., 2010; Mahdi and Khalequzzaman, 2012; Mutambuki, 2013; Mahgoub and Zewar, 2014). The efficacy of inert dusts against insects depends majorly on the physical properties of the dust. These characteristics contain particle size distribution, active exterior and oil adsorption, the diameter of internal pores of particles, moisture content of dust and SiO_2 content (Ebeling, 1971; Maceljski and Korunic, 1972). Desmarchelier and Dines (1987), Patourel (1986), Aldryhim (1990), (1993) mentioned that inert dusts are not directly toxic; they are relatively slow acting and typically become more and more effective with longer exposure times.

Our results are in agreement with the result of Abd-El-Salam et al. (2015) who mentioned that nano Al_2O_3 and amorphous nano SiO_2 were highly effective against *S. oryzae*. Comparing the efficacy of the inert dusts applied alone and in formulations with *L. officinalis* on *S. oryzae,* the efficiency of silicon dioxide or aluminum oxide alone was similar to these compounds in the formulations, except that, the mortality of *S. oryzae* treated with silicon dioxide and aluminum oxide formulations increased from 50% and 53.3% to 93.33%, respectively, after 2 days at first 50 days lifetime period. Likewise, kaolin formulation was more effective than kaolin alone, where the formulation achieved complete mortality after 21 days of exposure at 50 days lifetime period, while the compound alone did not record any complete of mortality at different lifetime periods.

Varma and Siddiqui (1977), Golob (1997) suggested that the silicates in kaolin could induce mortality by causing desiccation. Stanley (1998) mentioned that kaolin acts as a physical barrier preventing insects from reaching vulnerable plant tissue. It behaves like a repellent by creating an inappropriate surface for feeding or egg-laying. The regular white film may also injury the insect's host finding ability by coating the color of the plant tissue. Moreover, particles of kaolin behave as an irritant to the insect. Subramanyan and Roesli (2000), Mewis and Ulrichs (2001) reported that silica dusts make action by absorbing the oily or waxy outer cuticle layer of insect via direct contact, when the thin, waterproof layer of the epicuticle is lost, the insect forfeits water, and dies from desiccation. Accordingly, the tested inert dusts may cause the insecticidal activity via one or more of these modes of action.

4 Conclusion

Aluminum oxide was the most effective in controlling *S. oryzae,* followed by silicon dioxide. On the other hand, the cumulative mortality revealed that, silicon dioxide alone or in formulation was the most powerful, followed by aluminum oxide. Aluminum oxide and silicon dioxide formulations increased the efficiency on *S. oryzae* nearly two times than the compounds treated alone, after 2 days from exposure at first 50 days lifetime period. Likewise, kaolin formulation was more effective than kaolin alone at the same lifetime period. Therefore, the inert dusts, aluminum oxide, kaolin and silicon dioxide can used in formulations with *L. officinalis* against *S. oryzae.*

References

Abdel-Aziz, N. F., W. L. Abdou, E. A. Abdel-Hakim, F. M. El-Hawarya, A. M. El-Bakry, and E. A. Sammour. 2015. The effect of some green insecticides from essential oils on *Aphis craccivora*, and their side effects. *Journal of Entomological Research*, 39(4): 275–286.

Abd-El-Salam, A. S., A. M. Hamzah, and N. M. El-Taweelah. 2015. Aluminum and zinc oxides nanoparticles as a new method in controlling the red flour beetle, *Tribolium castaneum* (Herbest) compared to Malathion insecticide. *International Journal of Scientific Research in Agricultural Sciences*, 2(Proceedings): 1–6.

Aldryhim, Y. N. 1990. Efficacy of the amorphous silica dust, Dryacide ®, against *Tribolium confusum* Duv. and *Sitophilus granarius* (L.). *Journal of Stored Products Research*, 26(4): 207–210.

Aldryhim, Y. N. 1993. Combination of classes of wheat and environmental factors affecting the efficacy of amorphous silica dust, Dryacide®, against *Rhyzopertha dominica* (F.). *Journal of Stored Products Research*, 29(3): 271–275.

Allen, S. 2001. Integration of inert dust into control of storage pests in bulk grain in storage in Australia. In *Proc. the International Conference Controlled Atmosphere and Fumigation in Stored Products,* 279–284. Fresno, CA. 29 October-3 November.

Arthur, F. H., and J. E. Throne. 2003. Efficacy of diatomaceous earth to control internal infestations of rice weevil and maize weevil (Coleoptera, Curculionidae). *Journal of Economic Entomology*, 96(2): 510–518.

Costat. 2004. *Costat user's manual (Version 6.303).* Monterey. California: Cohort Software Inc.

Desmarchelier, J. M., and J. C. Dines. 1987. Dryacide ® treatment of stored wheat: its efficacy against insects, and after processing. *Australian Journal of Experimental Agriculture,* 27(2): 309–312.

Ebeling, W. 1971. Sorptive dusts of *Collosobruchus maculates* or pest control. *Annual Review of Entomology*, 16: 123–158.

El-Bakry, A. M., N. F. Abdel-Aziz, E. A. Sammour, and S. A. M. Abdelgaleil. 2016. Insecticidal activity of natural plant essential oils against some stored product insects and their side effects on wheat seed germination. *Egyptian Journal of Biological Pest Control*, 26(1): 83–88.

Fields, P. G. 1998. Diatomaceous earth: Advantages and limitations. In *Proc. the 7th International Conference on Stored-Product Protection,* 1: 781–784.

Finney, D. J. 1971. *Probit Analysis, 3rd* London: Cambridge Univ. Press.

Golob, P. 1997. Current status and future perspectives for inert dusts for control of stored product insects. *Journal of Stored Products Research*, 33(1): 69–79.

Goswami, A., I. Roy, S. Sengupta, and N. Debnath. 2010. Novel applications of solid and liquid formulations of nanoparticles against insect pests and pathogens. *Thin Solid Films*, 519(3): 1252–1257.

Heydarzade, A., and G. Moravvej. 2012. Contact toxicity and persistence of essential oils from *Foeniculum vulgare*, *Teucrium polium* and *Satureja hortensis* against *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae) adults. *Turkish Journal of Entomology DergiPark,* 36(4): 507–518.

Maceljski, M., and Z. Korunic. 1972. The effectiveness against stored-product insects of inert dusts, insect pathogens, temperature and humidity. Final Report of Institute for Plant Protection Project. No. E30-MQ-1. Grant USDA/YU No. FG-YU-130. Zagreb: Grant USDA/YU. Zagreb, p. 151.

Mahdi, S. H. A., and M. Khalequzzaman. 2012. The efficacy of diatomaceous earth in mixed formulation with other dusts and an insecticide against the pulse beetles, *Callosobruchus chinensis* L. and *Callosobruchus maculatus* (F.). *University Journal of Zoology, Rajshahi University*, 31: 73–78.

Mahgoub, S. M., and M. M. Zewar. 2014. Field and laboratory assessment of the efficacy of some inert dusts against some stored grain insects. *Egyptian Journal of Agricultural Research*, 92(1): 1–8.

McKevith, B. 2004. Nutritional aspects of cereals. British Nutrition Foundation. *Nutrition Bulletin*, 29(2): 111–142.

Mel'zina, E. N., S. J. Orekhov, A. N. Mironov, and M. M. Ryshkov. 1982. Mineral dusts as possible insecticides of pullecidal effect (Flea Siphonaptera control). *Meditsinskaya Parazitologiya I Parazitarnye Bolemi*, 51: 45–49.

Mewis, L., and C. Ulrich. 2001. Action of amorphous diatomaceous earth against different stages of the stored product pests *Tribolium confusum, Tenebrio molitor, Sitophilus granaries* and *Plodia interpunctella*. *Journal of Stored Products Research*, 37(2): 153–164.

Misra, G., and S. G. Pavlostathis. 1997. Biodegradation kinetics of monoterpenes in liquid and soil-slurry systems. *Applied Microbiology and Biotechnology*, 47(5): 572–577.

Mutambuki, K. 2013. The influence of grain moisture content on the efficacy of silica dust on *Prostephnus truncates* (horn) (Coleoptera: bostrichidae) and *Sitophilus zeamais* (motsch) (Coleoptera: curculionidae). *Journal of Stored Products and Postharvest Research*, 4(2): 23–29.

Patourel, G. N. 1986. The effect of grain moisture content on the toxicity of a sorptive silica dust to four species of grain beetle. *Journal of Stored Products Research*, 22(2): 63–69.

Quarles, W., and P. S. Winn. 1996. Diatomaceous earth and stored product pests. *The IPM Practioner*, 18(5/6): 1–10.

Rajashekar, Y., and T. Shivanandappa. 2010. A novel natural insecticide molecule for grain protection. In *10th International Working Conference on Stored Product Protection. Julius-Kühn-Archiv*, 425: 910–915.

Rajasri, M., P. S. Rao, and K. V. S. M. Kumari. 2012. Inert dusts-better alternatives for the management of angoumois grain moth, *Sitotroga cerealella* in stored rice. *International Journal of Science and Research (IJSR),* 3(10): 278–283.

Salem, H. A., N. F. Abdel-Aziz, E. A. Sammour, and A. M. El-Bakry. 2016. Semi-field evaluation of some natural clean insecticides from essential oils on armored and soft scale insects (Homoptera: Diaspididae and Coccidae) infesting mango plants. *International Journal of ChemTech Research*, 9(8): 87–97.

SPSS, 2012. *Statistical Package for Social Sciences (Version 21.0.).* Chicago, IL: SPSS Software Inc.

Stanley, D. 1998. Particle films, a new kind of plant protectant. *Agricultural Research Magazine*, 46(11): 16.

Subramanyan, B. H., and R. Roesli. 2000. Inert dust. In *Alternatives to pesticide in stored-products IPM*, B. Subramanyam, and D. W. Hagatrum, eds. 321-380. Norwell, Massachusetts: Kluwer Academic Publishers.

Varma, B. K., and M. K. H. Siddiqui. 1977. Control of storage pests through inert dusts. *Indian Farming*, 27: 21–25.