J. Agric. Sci. Mansoura Univ., 34 (12): 11459 - 11468, 2009

EFFICACY OF SOME INERT DUSTS AND THEIR MIXTURES ON SOME STORED PRODUCT INSECTS

Zayed, G.M.M.*, H.M. El-Zun* and S.I.A. Ibrahim**

*** Dept. of Stored Product Pests Res., Plant Protection Res. Inst., Agric. Res. Center, Giza, Egypt**

**** Pesticides Deptartment, Faculty of Agriculture, Kafrelsheikh University.**

ABSTRACT

The present study were carried out under laboratory conditions of 28 + 1ºC and 70 + 5% R.H. to evaluate the effectiveness of tricalcium phosphate (TCP) and diatomaceous earth dusts (DE) separately and mixtures against rice weevil; *Sitophilus oryzae* (L) and red flour beetle; *Tribolium castaneum* (Herbst). The results showed that the action of the two dusts and their mixtures depend on the concentration and period of exposure. *S. oryzae* was the more susceptible to the two tested dusts and their mixture compared to *T. castaneum*. All dual mixtures of TCP and DE were more effective to both tested insects at the all different concentrations and exposure periods except the mixture No. 3 (30% DE + 70% TCP) with *T. castaneum* which had the least effect after 2 weeks of exposure. Results obtained also showed that mixtures No. 3 had the highest percentage of mortality values compared to the other two mixtures. Results also showed that the all treatments had a significant effect on the percentages of germination and weight loss compared to control. The addition of DE to TCP can minimize the required amount of in insect control and decreases the cost of control.

So, the addition of DE to TCP can minimize the required amount of DE in insect control and decreases the cost of control where the DE agent is rarely available and expensive. In conclusion we recommend to use of DE, TCP and their mixtures in insect control of stored products where it is safe and cheap after further studies to ensure the obtained findings in the present study.

INTRODUCTION

Inert dusts such as ash, lime, various ground minerals and clays have a long history of use for grain protection (Ebling, 1971; Golob and Webley, 1980; Ross, 1981; Quarls, 1992a, b). There are several advantages to using inert dusts to control stored-product insect pests. In the United States, amphorpous silicon dioxide (diatomaceous earth) is considered "Generally Recognized as a Safe" (GRAS) by US Food and Drug Administration and is a registered food additive, silica aerogels have been shown to have low mammalian toxicity (3160 mg/kg LD_{50}, rat oral; Ebeling, 1971). Also, inert dusts do not affect backing quality (Desmarchelier and Dines, 1987; Aldryhim, 1990); and provide long lasting protection (La Hue 1965, 1978; White *et al.,* 1975).

Interest has revived in the use of inert dusts after neglect resulting from the outstanding success of chemical protectants. La Hu, 1978 showed a diatomaceous earth, kenite, added at 0.5 kg/t at 33ºC, 40% rh. reduced multiplication of *S. oryzae* and *S. zeamais* to one quarter of that on untreated grain over a 6 months storage period.

Now, inert dusts particularly those based upon activated silicas and plant powders are finding increasing use as storage protectants in the grain industry. These materials are not effective in conditions of low humidity because they induce mortality causing desiccation, water is low because the dusts remove waxy layer of cuticle of exoskeleton by adsorptions (Golob, 1997; Arthur, 2002, 2004 and Arthur *et al*., 2003).

The present study was conducted to evaluate the efficiency of two inert dusts diatomaceous earth, tricalcium phosphate and their mixtures against *S. oryzae* and *T. castaneum* at different periods and concentrations.

MATERIALS AND METHODS

1. Materials:

1.1. Insects:

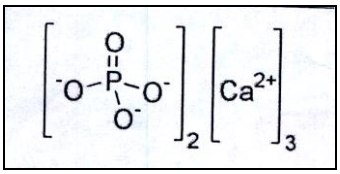
The considered insects in the current investigation were rice weevil, *Sitophilus oryzae* (L), (Curculionidae: Coleoptera) and red flour beetle; *Tribolium castaneum* (Herbst); (Tenebrionida: Coleoptera). The original stock culture of the insects was obtained from Stored Product Pest laboratory, Plant Protection Research Institute. The insects were reared on samples of Sakha 61 wheat grains for *S. oryzae* or wheat crushed for *T. castaneum* under laboratory conditions of 28 ± 1^{o}C and 70 ± 5% R.H.

1.2. Inert dusts:

1.2.1. Tricalcium phosphate dust (TCP):

Chemical name: calcium phosphate, tribasic.

Structure formula:



Empirical formula: $CA_3O_2P_2$

Source: Plant protection Research Institute-Sakha-Kafr El-Sheikh, Egypt, it was mixed with wheat grains at 0.5, 1.0, 2.0 and 3% (w/w%) concentrations.

1.2.2. Diatomaceous earth dust DE:

Chemical name: Silicon dioxide.

Source: It was purchased from Agrokaslet Co., Canada and Kindly was obtained from ARC, Dokki Giza, Egypt. It was mixed with wheat grains at 0.05, 0.1, 0.2 and 0.3% (w/w%) concentrations. The two materials were tested separately and in the following combinations:

Mixture No. 1:10% DE + 90% TCP
Mixture No. 2:20% DE + 80% TCP
Mixture NO. 3:30% DE + 70% TCP

Each mixture was evaluated at 0.5, 1.0, 2.0 and 3.0% w/w concentrations by mixing it with whole wheat grains, for *S. oryzaei* or crushed wheat grains for *T. castaneum*.

2. Methods:

2.1. Toxicity and reduction in progeny tests:

The appropriate amount of the tested powders either separately or in binary mixtures which give the required concentrations was mixed thoroughly with 100 g wheat for *S. oryzae* or crushed wheat grains for *T. castaneum,* then the treated media was introduced into glass jar each of 250 ml, twenty adults of 1 to 2 weeks old of *T.* castaneum and *S. oryzae* were transferred to each glass jar, *every* treatment was replicated three times. In addition three replicates of untreated media were kept as control. All jars were covered with muslin cloth, fixed with rubber band and kept at 28 + 1°C and 70 + 5% R.H. Mortality assessment was conducted after one and two weeks from treatment, alive insects were removed and reduction in F_1-progeny was calculated 2 months post-treatment according to the following equation (El-Lakwah *et al.,* 1992).

$$\% \text{ reduction} = \frac{\text{No. of emerged adult in control - No. of emerged adult in treamtent}}{\text{No. of emerged adult in control}} x100$$

2.2. Assessment of loss% wheat grain:

The weight loss of wheat grains and crushed wheat grains due to infestation with *S. oryzae* and *T. castaneum*, respectively was also determined two months after treatment for treatments or control by sieving the dusts and insects from treated media. The weight loss of wheat grains was calculated according to the following equation (Harris and Lindblad, 1978).

$$\% \text{ loss} = \frac{\text{Initial dry weight of grains - grains dry weight after 2 months}}{\text{Initial dry weight of grains}} \times 100$$

2.3. Germination tests:

According to Qi and Burkhoder (1981) with slight modification the germination tests were accomplished on treated wheat grains stored for two months. Sixty grain seeds of each treatment were divided into three replicates, placed on Petri-dishes containing cotton layer soaked with tap water and covered with tissue paper. After four days grain germination percentages were recorded.

Statistical analysis according to Duncan (1955) was used in this study.

RESULTS AND DISCUSSION

Results in Tables (1, 2, 3) indicated that the all studied parameters were highly affected by the different treatments (concentrations of DE, TCP and their mixtures). There were significant differences between the number of emerged adults and F_1 reduction percentages at the all tested concentrations of the tested material and their mixtures for the two studied insects. Results also showed that % germination and % loss of wheat grain by *S. oryzae* and *T. castaneum* were highly significantly affected by the different treatments. However, all treatments had nearly low effect on the germination (compared to the other tested parameters) by the exception the fourth concentration of both DE and mixtures No. 3, the germination ranged from (90-97%) in the remained treatments.

Table (1): Analysis of variance for the number of offspring of *S. oryzae* and *T. castaneum* exposured to diet admixed with diatomaceous earth, tricalcium phosphate and their mixtures.

S.O.V.	d.F	DE		TCP		Mix. No. 1		Mix. No. 2		Mix. No. 3	
		S.O.	T.C	S.O.	T.C	S.O	T.C	S.O	T.C	S.O	T.C
Re	2	22	654	651	199	41	341	126	45	110	232
Tret.	4	293809**	81328**	204094**	60737**	307071**	101438**	320789**	99254**	339148**	101887**
Er.	8	72	158	102	405	46	73	24	179	60	181
Total	14										

S.O. = *Sitophilus oryzae* **T.C. = *Tribolium castaneum***

Table (2): Analysis of variance of % adult reduction of *S. oryzae* and *T. castnaeum* exposured to diet admixed with mixtures of diatomaceous earth and tricalcium phosphate.

S.O.V.	d.F	M.S.(mean square)	
		S. oryzae	*T. castaneum*
Rep.	2	6.750	50.2
Treat.	11	74.286**	862.1**
Erro.	22	0.261	27.4
Total	35		

Table (3): Analysis of variance of % germination and % weight loss by *S. oryzae* and *T. castaneum* in tested treated diet by diatomaceous earth, tricalcium phosphate and their mixtures.

S.O.V.	d.F	M.S		
		% germination	% loss	
			S. oryzae	*T. castaneum*
Rep. (R)	2	21.16	5.17	1.79
Treat. (T)	20	42.89**	389.17**	63.92**
Error (E)	40	3.98	1.68	3.42
Total	62			

Toxic action of TCP and DE on *S. oryzae* and *T. castaneum*:

Results obtained in Table (4) showed that adults mortality of the two tested insects increased with the increase of concentrations or periods of exposure. Results indicated that DE provided the most effective control against the two stored product insect species, where concentration of 0.05% DE gave 80 and 91.7% mortality with *S. oryzae* at one and two weeks exposure periods,

respectively, while TCP was less effective against the tested insects since the concentration of 0.5% TCP caused 33.3 and 40.0% mortality with *S. oryzae* at the same periods of exposure, respectively. For *T. castaneum* also the DE was the most effective after the two periods post-treatment because the concentration of 0.3% DE achieved 51.6 and 60% mortality, respectively, while, 1.0% TCP treated diet gave 46.0 and 53.3% adult mortality at the two tested periods, respectively (Table 4).

Effect on progeny:

Results obtained in Table 4 also showed the same trend mentioned with toxicity, where the reduction % of progeny increased with the increasing of concentrations. In general the DE had the highest adversed effect on progeny of both *S. oryzae* and *T. castaneum*. Diet treated with 0.05% DE inhibited the emergence of *S. oryzae* and *T. castaneum* by 81.1 and 40.5%, respectively while that treated of 0.5% TCP reduced the produced progeny of both *S. oryzae* and *T. castaneum* by 55.9 and 36.9%, respectively.

Action of binary mixtures:

In general the results obtained in Table 5 had the same trend with inert dusts alone since the mortality increased with the increasing of concentrations or the exposure periods. With the exception of mixture 3 against the *T. castaneum* the remained mixtures had a good effect concerned to the reduction of progeny for the two tested insects. Results showed that the effect of mixtures was nearly equal to that of the single inert dusts except the mixture No. 3 with *T. castaneum* which had the least effect. All treatments significantly reduced the % weight loss and increased the reduction percentage of progeny compared to the control. Results in Table 6 showed that the two tested materials and their mixtures had low effect on the germination percentages of wheat grains if was compared by the other tested parameters.

The obtained results are in agreement with El-Lakwah *et al.,* 1999, 2000 and Abd El-Latif, 1999; who mentioned that DE was significantly more effective than Kalel-Sous at its recommended rate especially at the higher concentrations. Also, its effect against the adults of *T. castaneum* and active and diapausing larvae of *T. grarnarium* was reduced compared to *S. oryzae* and *R. dominica.*

Bioactivity of Katel-Sous and Diatomaceous earth mixtures was investigated by El-Lakwah *et al.,* 2001 on *S. oryzae*, *R. dominica* and *T. castaneum*. The results indicated that the bioactivity of the two dusts and their mixtures was concentration and exposure period-dependent. Adults mortality increased with the reign of the concentration and exposure period. *T. castaneum* was less sensitive to the two dusts and their mixtures as compared to the other two insect species. Zayed (2005) studied the effect of rice husk-ash and DE. separately and in mixtures on *S. oryzae* and *T. castaneum*. The results indicated that adult mortality increased with rising of concentration and exposure period. *T. castaneum* was less susceptible to the two dusts and their mixtures as compared to the *S. oryzae*.

4-5

Table (6): Effect of treating wheat grains with the DE, TCP and their mixtures on germination after 2 months of treatment.

Conc. %w/w	DE	Conc. %w/w	Treatment				
			TCP	Mix. No. 1	Mix. No. 2	Mix. No. 3	Control
0.05	96.0 f	0.5	94.0 def	97.0 fg	96.0 f	90.0 bc	100 g
0.1	95.0 ef	1	94.0 fg	95.0 ef	94.0 def	94.0 def	
0.2	91.0 cd	2	92.0 cde	90.0 bc	90.0 bc	92.0 cde	
0.3	84.0 a	3	90.0 bc	91.0 bc	90.0 bc	87.0 ab	

Demissie *et al.* (2008) evaluated the effectiveness of the diatomaceous earth Silicosec, a mineral industrial filter cake and domestic wood ash, applied at three different rates for the control of the maize weevil, *Sitophilus zeamais* on three maize genotypes. Treatment with silicosec was the most effective followed by filter cake and wood ash. The treatment reduced progeny emergence, percentage of grain damage and grain weight losses, but did not affect percentage seed germination. However, all treatments caused high mortality (97-100%) after 15 days of exposure.

Fig. (1) Effect of the three mixtures on the tested insect species after one and two weeks at 1% concentration comparing to TCP at its recommended rate of application (1% w/w).

Concerning the efficacy of the mixtures on *S. oryzae* (Fig. 1A), mortality data clearly show that mortality values from the different mixtures were obviously greater than those of TCP. Meanwhile, the mixture No. 3 was the most effective at various exposure periods of one and two weeks.

In case of *T. castaneum* (Fig. 1B) the effect of mixtures was either less or similar mortality values as compared to TCP for all mixtures and at various exposure periods. Results showed that the addition of DE to TCP enhanced the toxic property of TCP at overall of mixtures. So, the addition of DE to TCP can minimize the required amount of DE in insect control and decreases the cost of control where the DE agent is rarely available and expensive. In conclusion we recommend to use of DE, TCP and their mixtures in insect control of stored products where it is safe and cheap after further studies to ensure the obtained findings in the present study.

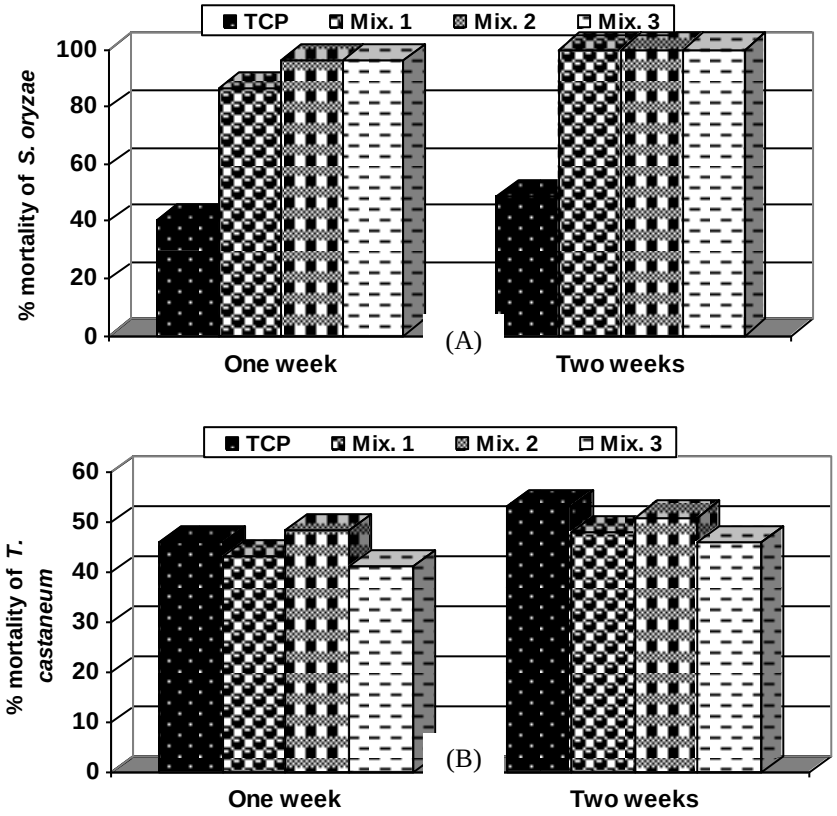


Fig. (1): Effect of the three mixtures at 1% w/w against S. oryzae (A) and T. castaneum (B) compared to TCP at its recommended rate (1% w.w)

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تأثير بعض المساحيق الخاملة ومخاليطها على بعض حشرات الحبوب المخزونة

جمال محمد محمود زايد* ، هشام مصطفى الظن* و سحر إبراهيم أحمد إبراهيم**
*** قسم بحوث آفات الحبوب المخزونة ـ معهد بحوث وقاية النباتات ـ مركز البحوث الزراعية ـ جيزة ـ مصر**
**** قسم المبيدات ـ كلية الزراعة ـ جامعة كفرالشيخ ـ مصر .**

لقد تمت هذه الدراسة تحت ظروف المعمل على درجة حرارة ٢٨ + ١°م ورطوبة نسبية ٧٥ + ٥ لمعرفة تأثير كل من مسحوق فوسفات ثلاثى الكالسيوم والتربة الدياتوميه كل على حده وكذا بعد خلطهما معا بنسب محددة ضد بعض حشرات المنتجات المخزونة وهى سوسة الأرز وخنفساء الدقيق الصدئية. وأوضحت النتائج أن التأثير الإبادى لكلا المسحوقين منفردين ولمخاليطهما يعتمد على التركيز المستخدم ومدة التعريض. ولقد أظهرت خنفساء الدقيق الصدائية تحملا أكثر من سوسة الأرز لكل من المساحيق السمتخدمة ومخاليطها. تأثير المخاليط كان مساويا تقريبا للمساحيق المنفردة فيما عدا المخلوط رقم ٣ (٣٠% تربة دياتوميه + ٧٠% فوسفات ثلاثى الكالسيوم) الذى أظهر تأثيرا ضعيفا ضد خنفساء الدقيق الصدئية الحمراء. أدى استخدام المساحيق منفردة أو فى مخاليط إلى خفض تعداد الحشرات الناتجة من كلا الحشرتين وكذا تقليل الفقد فى الوزن مقارنة بالكنترول. كان لاستخدام المساحيق المنفردة أو مخاليطها تأثيرا منخفضا على مستوى إنبات حبوب القمح بعد المعاملة بشهرين مقارنة بالتأثير على باقى الصفات المدروسة. كذلك أدى اضافة التربه الدياتومية لثلاثى فوسفات الكالسيوم إلى تحسين خواصه وخفض تكاليف المكافحة فى هذه الدراسة.

توصى النتائج باستخدام المساحيق المنفردة أو مخاليطها المستخدمة فى هذه الدراسة نظرا لآمانها وانخفاض تكلفتها وقدرتها العالية فى مكافحة هذه الحشرات. وذلك بعد اجراء دراسات مستقبلية لتأكيد النتائج المتحصل عليها فى هذه الدراسة.

قام بتحكيم البحث

أ.د / سمير صالح عوض الله	**كلية الزراعة – جامعة المنصورة**
أ.د / رأفت بدر أبو عرب	**مركز البحوث الزراعية**

Table (4): Effect of inert dusts diatomaceous earth and tricalcium phosphate admixed with the wheat grains and wheat crushed grains on *S. oryzae* and *T. castaneum* at the different periods after treatment.

Inert dusts	Conc. % w/w	% adult mortality after indicated period (weeks)				No. of emerged adults after 2 months (F_1 progeny)		Reduction % (F_1 progeny)		Loss % of diet weight after 2 months	
		S. oryzae		*T. castaneum*		*S. oryzae*	*T. castaneum*	*S. oryzae*	*T. castaneum*	*S. oryzae*	*T. castaneum*
		1	2	1	2						
Diatomaceous earth dust	0.05	80.0	91.7	16.0	24.0	148 d	280 d	81.1 a	40.5 a	43.0 ef	6.0 a
	0.1	93.3	100	26.6	28.3	115 c	242 c	85.4 b	48.65 b	2.9 c-f	4.9 a
	0.2	100	-	40.0	46.0	72 b	102 b	90.8 c	78.3 c	2.0 a-e	3.0 a
	0.3	-	-	51.6	60.0	33 a	53 a	95.8 d	88.7 d	1.0 a-d	2.0 a
Calcium triphosphate dusts	0.5	33.3	40.0	40.7	46.6	346 d	297 c	55.9 a	36.9 a	7.0 g	5.0 a
	1	40.0	48.3	46.0	53.3	285 c	267 c	63.7 b	43.3 b	5.0 fg	4.0 a
	2	63.3	71.6	61.3	68.3	217 b	186 b	72.4 c	60.5 c	4.0 ef	2.5 a
	3	75.0	86.6	65.0	80.0	103 a	88 a	86.9 d	81.3 d	2.1 a-e	2.0 a
Control						785 e	471 de			54.0 h	24.0 b

Table (5): Effect of mixtures of tricalcium phosphate and diatomaceous earth dusts against *S. oryzae* (S.O.) and *T. castaneum* (T.C) recorded at different periods after treatment.

Treatment	Conc. % w/w	% adult mortality after indicated period (weeks)				F_1 progeny after 2 months		Reduction % (F_1 progeny)		Loss % of diet weight after 2 months	
		S. oryzae		*T. castaneum*		*S. oryzae*	*T. castaneum*	*S. oryzae*	*T. castaneum*	*S. oryzae*	*T. castaneum*
		1	2	1	2						
Mixture No. 1	0.5	84.0	98	33.0	40.0	136 d	275 c	82.7 a	41.6 a	3.7 ef	5.5 a
	1	86.6	100	43.3	48.0	86 c	79 b	89.0 c	83.2 de	2.5 b-e	4.3 a
	2	93.0	-	49.4	54.0	47 b	68 b	94.0 e	85.6 def	1.0 a-d	3.0 a
	3	100	-	51.6	60.0	32 a	42 a	96.0 f	91.0 f	0.5 abc	2.0 a
Mixture No. 2	0.5	92.0	100	36.0	43.3	120 c	220 c	84.7 b	53.3 c	3.5 ef	4.5 a
	1	95.0	-	48.3	51.0	51 b	92 b	93.0 d	80.5 d	2.0 a-e	4.0 a
	2	97.0	-	52.0	60.0	33 a	51 a	95.74 f	89.0 def	1.0 a-d	3.5 a
	3	100	-	58.0	65.0	24 a	32 a	97.0 f	93.2 f	0.3 ab	2.0 a
Mixture No. 3	0.5	93.0	100	39.0	40.0	60 c	215 c	92.3 d	54.4 b	3.0 def	4.0 a
	1	96.0	-	41.3	46.0	42 b	91 b	94.6 e	80.6 d	2.0 a-e	3.0 a
	2	98.3	-	58.0	60.0	20 a	46 a	97.5 gh	90.2 def	0.7 a-d	2.5 a
	3	100	-	61.3	64.0	15 a	23 a	98.0 h	95.1 f	0.1 a	2.0 a
Control						785 ed	471 d			54.0 h	24.0 b