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Comparative Insecticidal Activity of Three Forms of Silica Nanoparticles on some Main Stored Product Insects

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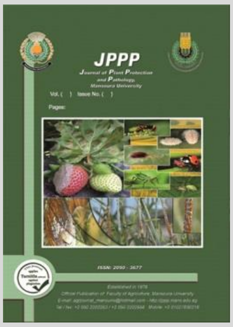

ABSTRACT

The control of stored grain pests requires effective materials that are save for humans and environment, low cost, available and easy to obtain and do not need trained labor. Therefore, the current study suggested testing three silica forms in the form of nanoparticles, these were Aerosil 200, chemical and bio-silica for controlling *Callosobrochus maculatus* F. (Col., Bruchidae), *Rhythopertha dominica* fab, and *Tribolium confusum* (Jacquelin du Val). The obtained results showed that the percent mortality increased with the increasing of concentration and exposure period. Moreover, all the tested materials of nanoparticles had detrimental induction on mortality and offspring of the three tested insects. In addition the adults of *C.maculatus* were more susceptible followed by *R.dominica* and *T.confusum* with the three tested materials at the all concentrations used. Data obtained revealed that the activity of chemical silica had the first rank followed by Aerosil 200 and bio-silica where the LC50 of chemical silica ranged between 0.14-1.54 one day posttreatment with significant distinction compared to Aerosil 200 (0.15-2.65) and bio-silica (2.43-7.35)g/kg grain. The findings obtained showed that the three forms of silica had deterrent action on the all tested immature stages at the all levels of concentrations. Also results clarified the egg stage was the most susceptible compared to larvae and pupae ones. The all treatments reduced the emerged adults and the losses of grain weight. Consequently the present study explained that the three used forms of silica are promising materials for controlling the tested insects as safe alternatives to the synthetic insecticides.

Keywords:- *Tribolium confusum, Rhythopertha dominica, Callosobrochus maculatus*, nanoparticles, Aerosil 200, chemical and bio –silica.

INTRODUCTION

Stored products are subjected to attack by numerous of insects which reduce weight and quality. Stored product insect pests are responsible for considerable quantitative and qualitative losses of agricultural products mainly cereals and legumes (Philips and throne 2010). Many disorders of human health and environment often due to overuse of chemical synthetic insecticides against the insect attack both in field and storage. Consumer demands products free of chemical and insect contamination to the application of non-residual technologies for the protection of stored product grains. Meanwhile, we must be needed to study and apply eco-friendly methods and techniques to reduce pesticides use during maintaining crop yields. Nanotechnology has become one of the most approaches for best control recently. Nanotechnology is a new promising field of research; it is show a wide range in various fields like insecticides, agriculture and pharmaceuticals. Nanotechnology gives major impulses to technical innovations in the future (Leidere and Dekorsy 2008, Subramanyam and Roesli 2000). Nanoparticles represent a new generation of environmental remediation technologies that could provide cost-effective solution to some of the most challenging environmental clean-up problems (Chinnamuth and Boopathi 2009, Abo-Arab *et al* 2014). Application of nanosilica against different insect species showed up to complete mortality (Debnath *et al* 2010). The physical, biological and chemical properties of nanoparticles are associated with their atomic strength. Recently, several researches have been carried out to investigate the toxicity effect of nanoparticles on insects especially storage pests, Wan *et al* 2005, Yang *et al* (2009), Stadler *et al* 2010, Debnath *et al* 2012, Abo Arab *et al* 2014, Salem *et al* 2015, Arumugam *et al* 2016,Ali *et al* 2017, and Ibrahim and Salem 2019. Moreover, there is an old tradition of using silica dust as protective agent for stored seeds over the world (Ebeling, 1971). Aerosil 200 nanoparticles (fumed silica with size of 5-50 nm) synthetic amorphous silica composed of (99.8% Sio_2) was used as a desiccating agent to kill insects (Dorota *et al* 2010).Zeolite nanoparticles (aluminosilicate) can be effectively replacing chemical insecticides to protect stored grains from infestation with stored product insect pests. (Ibrahim and Salem 2019) Nanoparticles zeolite (aluminosilicate) is considered non-toxic and safe for human consumption (International Agency for Research on Cancer IARC 1997a, b). Moreover, it has been listed by Codex Alimentarious Commission (1999) as granted substance in organic food production and in plant protection. Amorphous silica was classified as not carcinogenic, where belongs to group 3 according to the International Agency for research cancer (IARC). The pest causes damage ranging from 5 to 30% of the world's total agricultural production (Mohammed 2013). The confused flour beetle *T. confusum* Jacquelin du Val (Col., Tenebrionidae) is one of the most important pests in flour mills which cause damage to commercial grain products. They are secondary pests that feed on broken kernels,seed

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embryos and grain dust (Mahroof and Hagstrum 2012). The cowpea weevil, *C. maculatus* F.(Col., Bruchidae), is one of the major pest of many stored products of legumes such as cowpea, chickpea, green gram, black gram, red gram, lentil, and soya bean (Edde and Amatobi 2003) ,as well as lesser grain borer *R. dominica* fab is one of the several serious pests of stored grains and other foodstuffs worldwide. Its known as a primary pest of stored grain because it eats the grain especially the germinal region causing economic loss (Hill 2002, Klys 2006and Shafighi *et al* 2014) . Therefore, this investigation focused on the effect of different forms of nanosilica as a possible alternative to traditional pesticides to control the main stored product insects, *T.confusum*, *R.dominica*, and *C.maculatus* through toxicity, biology assays and their effects on immature stages of *C.maculatus* as well as investigate the weight loss and % reduction of F1emerged adults.

MATERIALS AND METHODS

The experiments of the present study were conducted at the Laboratory of Department of Stored Product Pests, Plant Protection Research Institute, Sakha Agricultural Research Station, Kafr El-sheikh, Egypt.

Insects used:-

***Callosobrochus maculatus*:-**

Cowpea weevil *C.maculatus* was reared in the laboratory-controlled chamber (incubator) at 30± 5°C and 70± 5% relative humidity (R.H). Newly emerged adults were distinguished into male and female and then used in the next experiments at (0-2 day old).

***T.confusum and R.dominica*:-**

Adults of *T.confusum* and *R.dominica* were obtained from cultures were regularly maintained in the laboratory for several generations. The medium used for insect culture was crushed wheat grains for *T.confusum* and sound wheat grains for *R.dominica*. Once adults emerged, were used in the next experiments at (7-14) day old.

Nanoparticle materials:-

Three forms of silica used in this study namely, Aerosil 200 nanoparticles (fumed silica) obtained from Taiba Company for scientific services, Egypt, Bio-silica obtained from the husks of rice grain (RHs) and chemical silica, prepared in laboratory, with a diameter ranging from 3 to7 nm nearly according to Wang *et al* (2011).

Insecticidal activity of nanoparticles used:-

a.Contact toxicity bioassay:-

Three formulations of silica were investigated herein. The effectiveness of Aerosil 200, chemical and bio-silica were evaluated against three of the main stored product insect pests, mentioned above by using (mixing with medium method). Preliminary tests were carried out to define the considerable concentrations. The concentrations of 0.5, 1.0, 1.5, and 2.0 g/kg were for Aerosil 200 and chemical silica, while 2, 4, 6 and 10 g/kg were concerned with bio-silica. Twenty grams of medium suitable of each insect were transferred to plastic vials and then treated with the above mentioned concentrations; the vials were shaken well to achieve equal distribution in the grains and toxicants. Vials contain grains without silica nanoparticles were used for control. Each concentration and control was replicated trice. Five pairs of unsexed adults of *R.dominica* and *T.confusum* (7-14 day old) as well as five males and five females of *C.maculatus* (0-2 day old) were added to each vial, separately. The vials were covered with muslin cloth and kept in laboratory conditions. Mortality was recorded at 1, 3, 5, 7 and 10 days post-treatment, insects were considered dead when no leg or antenna movements were observed. The lethal concentration (LC50) of tested material was estimated using the probit analysis program (Finney 1971).

B. Impact of biology:-

After the final mortality counts of tested insects has been recorded, all remainder insects (dead and alive)were removed from the vials ,and then kept under the same conditions mentioned above for 60 days post treatment and new emerged adults were recorded.

C. Effect on immature stages:-

According to Thoraya *et al* (2012) and Salem (2014) three groups of vials (6 cm length, 4 cm diameter) each contains 10g of fresh and sterilized cowpea seeds (twelve vials for a group were infested by five females and five males (0-2 day old) in order to egg laying. The vials were covered with muslin cloth and kept at laboratory conditions 30 ± 5°C and 70 ± 5% RH. The adults were removed after 48h. Three replicates were used with each concentration. For egg stage the first group which contains the laying eggs was treated with the desirable concentrations of the three toxicants directly after removing the adults. After 7 days of egg laying ,the seeds contain the larval stage (The second group) were treated with the same mentioned concentrations. Like the third group which contains the early pupa was treated after 18 days. For the three groups observations were conducted daily till emergence of adults and then a fourth group left without toxicants and used as control. Calculation of percent reduction of F1 as well as cowpea seed weight loss was carried out according the following equations.

$$\text{Weight loss }\% = \frac{\text{Initial dry weght - Final dry weight}}{\text{Initial dry weight}} \times 100$$

$$\text{Reduction}\% = \frac{\text{Emerged adults in control - Emerged adults in treated}}{\text{Emerged adults in control}} \times 100$$

Statistical analysis:-

Statistical analysis of the current study was done through Duncan Multiple Rang Test (Duncan 1955).

RESULTS AND DISCUSSION

Results

Three formulations of silica were investigated in the present study namely, Aerosil 200, chemical and bio-silica nanoparticles. The results in Table (1) comprised the influence of Aerosil 200 against the above mentioned insects showing that Aerosil 200 effect increased when the concentration and the time period increased with the three tested insects. *C.maculatus* adults were the most susceptible among the tested insects followed by *R.dominica* and *T.confusum*. For example the level of 2g/kg grain achieved 100% mortality after 1, 2 and 10 days of treatment for *C.maculatus*, *R.dominica* and *T.confusum*, respectively. Except the rate of 0.5g/kg for *T.confusum*, the remained levels of concentration completely prevented the emergence of adults (F1).

The results shown in Table (2) showed the effect of chemical silica nanoparticles on the mortality of the three tested insects. Similarly, the results had the same trend of Aerosil 200, where the *T.confusum* adults were more tolerant than the other two insects tested. In addition, except the 0.5g/kg for *T.confusum* tested concentrations actualized 100% reduction to the F1 of emerged adults for the three studied insects.

Table 1. % mortality resulting from Aerosil 200 against the three tested insects at the indicated periods.

Concentration g/kg	Indicated periods (in day)					
	Tribolium confusum					
	1	**3**	**5**	**7**	**10**	**% reduction of F1**
0.5	16.7	23.3	40.0	50.0	73.3	70.0
1.0	26.7	36.7	50.0	60.0	80.0	100
1.5	30.0	50.0	63.3	70.0	86.7	100
2.0	43.3	60.0	83.3	90.0	100	100
	Rhyzopertha dominica					
0.5	56.7	83.3	96.7	100	___	100
1.0	76.7	90.0	100	___	___	100
1.5	83.3	93.3	100	___	___	100
2.0	93.3	100	___	___	___	100
	Callosobrochus maculatus					
0.5	56.7	83.3	100	___	___	100
1.0	76.7	93.3	100	___	___	100
1.5	90.0	100	___	___	___	100
2.0	100	___	___	___	___	100

Table 2. % mortality resulting from chemical Silica nanoparticles against the three tested insects at the indicated periods.

Concentration g/kg	Indicated periods (in day)					
	Tribolium confusum					
	1	**3**	**5**	**7**	**10**	**% reduction of F1**
0.5	20.0	30.0	46.7	60.0	86.7	78.8
1.0	26.7	43.3	56.7	70.0	80.0	100
1.5	40.0	50.0	70.0	86.7	90.0	100
2.0	66.7	76.7	90.0	100	___	100
	Rhyzopertha dominica					
0.5	60.0	86.6	100	___	___	100
1.0	80.0	93.3	100	___	___	100
1.5	90.0	96.6	100	___	___	100
2.0	100	___	___	___	___	100
	Callosobrochus maculatus					
0.5	60.0	86.7	100	___	___	100
1.0	80.0	96.7	100	___	___	100
1.5	93.3	100	___	___	___	100
2.0	100	___	___	___	___	100

For the action of bio-silica nanoparticles, the Table (3) summarized the obtained results. *C.maculatus* adults were more susceptible with the all tested materials, Aerosil 200, chemical and bio-silica nanoparticles at the all tested concentrations. Except the rate of 10g/kg grain the remained concentrations from 2 to 6g/kg failed to achieve 100% reduction in progeny of *T.confusum* F1. In contrast the all concentrations except 2g/kg implemented 100% reduction in F1 progeny for *R .dominica* and *C.maculatus*. In general, the all tested compounds effectuated moderate action against the three tested insects. In addition the adults of *C.maculatus* were the most susceptible followed by *R.dominica* and *T.confusum*. Moreover, the chemical silica nanoparticles were the premier followed by Aerosil 200 and bio-silica nanoparticles.

Table 3. % mortality resulting from bio-Silica nanoparticles against the three tested insects at the indicated periods.

Concentration g/kg	Indicated periods (in day)					
	Tribolium confusum					
	1	**3**	**5**	**7**	**10**	**% reduction of F1**
2.0	0.0	10.0	20.0	30.0	50.0	51.3
4.0	16.7	30.0	50.0	60.0	73.3	70.8
6.0	30.0	40.0	63.3	70.0	83.3	82.0
10.0	45	63.3	76.7	100	____	100
	Rhyzopertha dominica					
2.0	10.0	16.7	26.7	36.7	56.7	60.0
4.0	20.0	40.0	56.7	63.3	70.0	100
6.0	36.7	46.7	63.3	73.3	86.7	100
10.0	70.0	83.3	90.0	100	___	100
	Callosobrochus maculatus					
2.0	36.7	43.3	50.0	56.7	73.3	68.6
4.0	70.0	83.3	90.0	100	___	100
6.0	80.0	93.9	100	___	___	100
10.0	93.3	100	___	___	___	100

Table (4) contained the potential toxicity of the investigated materials showing that the three toxicants achieved toxicity with the all rates of concentrations illuminating that the chemical silica had the first rank followed by Aerosil 200 and bio-silica against the three tested insects. For example, the LC50 of chemical silica ranged between 0.14-1.54 one day post treatment with significant distinction compared to Aerosil 200 (0.15-2.65) and bio-silica (2.43-7.35 g/kg grain). Moreover the results evidenced that *T.confusum* was the tolerant insect followed by *R.dominica* and *C.maculatus.*

Table 4. Comparative toxicity of Aerosil 200, chemical and bio-silica nanoparticles against the tested insects at the indicated periods of exposure.

Toxicant	Time in day	*T.confusum*		*R.dominica*		*C.maculatus*	
		LC_{50}	C.L.	LC_{50}	C.L.	LC_{50}	C.L.
Aerosil 200	1	2.65	3.76-2.13	0.42	0.49-0.34	0.15	0.19-0.11
	3	1.47	1.74-1.25	0.23	0.28-0.17	0.08	0.11-0.05
	5	0.81	1.06-0.35	0.16	0.20-0.10	___	______
	7	0.62	0.93-0.42	___	______	___	______
	10	0.26	0.39-0.17	___	______	___	______
Chemical silica	1	1.54	2.31-1.03	0.37	0.44-0.29	0.14	0.19-0.04
	3	1.06	1.59-0.71	0.19	0.25-0.13	0.07	0.10-0.05
	5	0.67	1.00-0.45	___	______	___	______
	7	0.45	0.68-0.30	___	______	___	______
	10	___	______	___	______	___	______
Bio-silica	1	7.35	7.98-6.83	6.91	11.85-5.27	2.43	2.74-2.13
	3	5.61	7.85-3.92	4.02	4.69-3.56	1.61	2.41-1.07
	5	3.97	4.37-3.55	2.69	4.04-1.80	1.35	2.01-0.89
	7	3.15	4.73-2.10	2.16	2.98-1.24	1.20	1.80-0.80
	10	1.99	2.47-1.34	1.53	2.30-1.02	___	______

C.L:- confidence limits.

Data acquired in (Table 5) showed that, the three forms of silica induced deterrent action on the all tested immature stages at the investigated concentrations .Results also revealed that egg stage was more responsed than larvae and pupae while the pupae phase was the least one. Moreover, there were significant differences between and inside transactions. Also the all treatments reduced the emerged adults compared to control treatment. In addition the reduction of emerged adults parallel with the losses of grain weight, since the % losses of grain weight increased with increasing of emerged adults. Finally, the chemical silica ranked first followed by Aerosil 200 and bio-silica. For instance the level of 2g/kg of Aerosil achieved 100%&, 0.1, 100%&0.1 and 91.8&0.5% reduction of emerged adults and weight loss with egg, larval and pulpal stage, respectively. For chemical and bio –silica, the same level produced (100&0.1) (32.9&4.5), (100%&0.1), (28.7&5.0) and (93.8&0.5) and (23.3&5.0%) with the three stages mentioned above, respectively compared to control which presented 7.5%weight loss. Eventually, the three tested materials are considered promising alternatives of chemical pesticides for protecting the wheat grains and cowpea seeds in this study.

Table 5. Effect of three forms of silica nanoparticles against the immature stages of *C.maculatus.*

Toxicant		Egg stage			Larval stage			Pupal stage		
		Average of emergence	%R	%weight loss	Average of emergence	%R	%weight loss	Average of emergence	% R	%weight loss
Aerosil 200	0.5	27.0±2.64d	68.6	2.3	31.7±2.88d	63.0	2.5	37.0±2.00d	57.0	2.5
	1.0	16.7±1.54f	80.5	1.5	20.0±2.64e	76.7	1.8	24.3±1.15f	71.7	1.9
	1.5	10.3±2.51gh	88.0	0.8	15.3±2.51f	82.0	1.7	17.3±1.15gh	79.0	1.5
	2.0	0.00±0.00i	100.0	0.1	0.0±0.00i	100.0	0.1	7.00±1.73kg	91.8	0.5
Chemical silica	0.5	19.3±1.15ef	78.0	1.6	19.7±0.67e	77.0	1.6	22.3±2.51fg	74.0	2.0
	1.0	11.7±2.88g	86.4	1.2	14.3±3.21fg	83.7	1.0	18.3±2.51gh	79.0	1.5
	1.5	7.0±1.01h	90.3	0.7	10.7±1.15gh	87.6	0.9	11.7±3.61hi	86.4	0.8
	2.0	0.00±0.00i	100.0	0.1	0.00±0.00**i**	100.0	0.1	5.30±0.57k	93.8	0.5
Bio-silica	2.0	57.7±2.51b	32.9	4.5	61.3±3.21b	28.7	5.0	66.0±3.29b	23.3	5.0
	4.0	43.7v2.54c	49.2	3.3	49.7±1.52c	42.0	4.0	51.7±2.89c	40.0	4.0
	6.0	21.3±1.52e	75.2	2.0	27.7±2.51d	67.8	2.5	30.0±2.01e	65.0	2.8
	10.0	0.00±0.00i	100.0	0.1	8.70±1.15h	90.0	0.8	11.3±1.15ij	86.9	0.8
Control	___	86.0±3.61a	____	7.5±3.61	86.0±3.61a	____	7.5±3.61	86.0±3.61a	____	7.5±3.61

%R:- % Reduction of progeny

Discussion

Stored grain pests management relied mainly on synthetic pesticides which pose serious dangers to human and environment, in addition lead to pesticides resistance. To avoid the disadvantages of synthetic insecticides the current study suggested three rational alternatives to protect the stored grain, these are Aerosil 200, chemical and bio-silica nanoparticles ,through toxicity, F1 generation as well as assess their effects on immature stages of *C.maculatus* . Nanoparticles have much attention in recent years for controlling pathogens in agriculture (Eleka *et al* 2010, Sang woo *et al* 2009), and stored product pests (Wan *et al* 2005, Yang *et al* 2009, Stadler *et al* 2010,Wang *et al* 2012, Abo Arab *et al* 2014 , Salem *et al* 2015 and Rumbas *et al* 2016). The obtained data revealed that, all tested formulations achieved significant effect against the three tested insects compared to control. Moreover it was found that, the toxicity of tested materials depends on the time of exposure, concentration and insect species. As the concentrations and periods of exposure increased, the adults mortality increased. As for example the rate of 0.5g/kg of Aerosil 200 gave (16.7, 40), (56.7, 96.7) and (56.7, 100) after one and five days with *T.confusum*, *R.dominica* and *C.maculatus*, respectively. While the rate of 2.0g/kg gave 100% mortality after 10, 3, 1 days for *T.confusum*, *R.dominica and C.maculatus*, respectively. These findings confirmed with El-Bendary and El-Helaly (2016) who concluded that, mortality percentage found to has ascending relationship with time of exposure and concentration, as well as Doaa and Nilly (2015) evaluated the efficacy of Aerosil 200 NPs against *C.maculatus*, *R.dominica* and *S.oryzae* and concluded that Aerosil 200 exhibited significant strong toxic effect (mortality %), where the accumulative mortality rate increased with the increasing of the concentration and exposure intervals. Results obtained also achieved that, *C.maculatus* adults were the most susceptible among the tested insects followed by *R.dominica* while, *T.confusum* adults were the tolerant one. Masumeh and Zahra (2016) tolled that, in all tests *R.dominica* adults were more susceptible than *T.confusum*. Similarly (Athanassiou *et al* 2007), concluded that, *R.dominica* adults were more susceptible than *T.confusum* when exposed to maize treated with three different diatomaceous earth (DE), as well as *Tribolium SPP* are considered as the most tolerant species to DE among stored product insects (Kljajic *et al*(2010).Moreover, the obtained results explained that, all concentrations of both Aerosil 200 and chemical silica completely prevented the emerged adults of the three tested insects except the rate of 0.5 with *T.confusum*. Like the rate of 10g/kg of bio-silica was caused 100% reduction (F1). In contrast to concentrations of (2-6 g/kg) which failed to give 100% reduction with *T.confusum*. Concerning to *R.dominica* and *C.maculatus*, all concentrations recorded 100% reduction of progeny except 2g/kg, and these results may be due high mortality, disruption of mating behavior as a result of desiccation and spiracle blockage caused by nanoparticles used and the results are in accordance with (Kljajic 2010) who recorded that progeny suppression of *S.oryzae* and *T.castaneum* to be 80-95% on wheat treated with zeolite (aluminosilicate) at 0.75g/kg and concluded that this reduction of F1 generation due to desiccation and spiracle blockage of insects by zeolite nanoparticles. Additionally nanoparticles could have prevented the mating as a result of desiccation or blockage of spiracles and surface enlargement of integument as consequence of dehydration (Voigt *et al* 2009). Complete reduction in F1 progeny was recorded by Doaa and Nilly (2015) at all concentration used of Aerosil 200 with *C.maculatus* and *R.dominica* except the lowest concentrations (0.25g/kg grain). Similar results were concluded by Ali *et al* 2017; they reported that, there was no egg laying or hatching could be detected for adults of *C.chinensis* exposed to the concentrations of 1.0 and 2.0 g/100g nano Silica Particles NSPs as well as no emerged adults. Nevertheless, Katroju *et al* 2017 concluded that, silicon dioxide and silica NPS at 0.5 and 0.25 g/kg against cigarette beetle *Lasioderma serricorne* (Fabricus) caused higher mortality, reduced oviposition and adults emergence and has a great promise in cigarette beetle management. The findings obtained in the current study explained that all three forms of silica had deterrent action against the three tested immature stages of *C.maculatus* at all concentrations used, the youngest stage (egg) was most susceptible followed by larvae and pupae .In this regard (Ibrahim and Salem 2019) declared that, reduced adult longevity, oviposition, with adverse negative effect on eggs subsequently the % of emergence of *C.maculatus* adults were reduced affected by Zeolite nanoparticles as well as Rouhani *et al* (2012) reported that silica and silver nanoparticles were highly have a physical mode of action and act like diatomaceous earth (DEs) where, the particles absorb the insect wax layer, causing death through desiccation and to a lesser degree by abrasion (Ebeling 1971). The high insecticidal potential of Silica nanoparticles activity could be attributed to the Sio_2 content and nanometer size range of the particles which increase the ratio of the surface area to volume which increased insect contact with particles leading to more cuticle desiccation and death (Masumeh and Zahra 2016). Aerosil 200 known by its absorption characters when applied, the insects began to lose water due to damage of the water barrier (Debnath *et al* 2011) this hypothesis for the physical mode of action makes the nanocides were strong . It must be concluded that, silica nanoparticles could be effective to apply for protection of stored grain against pest attack at low concentrations considering the moisture content of commodities which affect the activity of silica, eventually. The physical mode of action make using nanoparticles valuable, besides it can be easily removed by conventional milling process unlike sprayable formulations of conventional pesticides on the stored grain (Debnath 2011 and vanic and Brindhaa 2013)for, Hydrophilic nano silicate will have an excellent potential agent to control stored grain pests at rates of 2g/kg seeds. Finally, (Debnath *et al* 2012) studied the in vitro cellular toxicity of silica nanoparticles in human fibroblast cell lines and acute oral toxicity in mice. They declared that the nanosized form is relatively non-toxic. However, further studies are required to sure the non-toxicity of nanosilica.

CONCLUSION

In this study, the insecticidal effect of nanosilica Aerosil 200, chemical and bio silica were evaluated. The obtained results revealed that the three forms of nanosilica can be used as a safe and low-cost nanocide to control *T.confusum*, *R.dominica* and *C.maculatus* adults and its efficacy varied depending on the concentration rates, exposure intervals and insect species. *C.maculatus* adults were more susceptible followed by *R.dominica* and *T.confusum*. The activity of chemical silica was the first rank followed by Aerosil 200 and biosilica. Nano silica can be effectively replacing chemical insecticides to protect stored products where they have a best effect on the stages of an insect. Further research is needed to investigate the effect of above-mentioned factors on the insecticidal efficacy of nanosilica against stored-product insects.

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مقارنة التأثير الابادي لثلاث صور من السيليكا النانومترية علي اهم آفات الحبوب المخزونة.

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تتطلب مكافحة آفات الحبوب المخزونة مواد فعالة متاحة وسهل االحصول عليها، قليلة التكلفة، آمنة علي الانسان والبيئة ولا تحتاج الي العمالة المدربة لذلك اقترحت الدراسة الحالية إختبار ثلاثة صور من دقائق السيليكا هي ايروسيل ٢٠٠، السيليكا الكيميائية و السيليكا الحيوية في مكافحة خنفساء الدقيق المختلطة، ثاقبة الحبوب الصغري و خنفساء اللوبيا أظهرت النتائج المتحصل عليها زيادة نسبة الموت مع زيادة التركيز وفترة التعريض و أظهرت المواد المختبرة تاثيرا ضارا علي نسبة الموت وإنخفاض في اعداد الخلفة الناتجة (الجيل الاول) مع الحشرات الثلاثة المختبرة بالإضافة الي ذلك اظهرت النتائج ان حشرة خنفساء اللوبيا كانت اكثر حساسية تليها ثاقبة الحبوب الصغري ثم خنفساء الدقيق مع كل المواد المختبرة عند كل التركيزات المستخدمة. وأظهرت النتائج المتحصل عليها ان السيليكا الكيميائية كانت في المرتبة الاولى يليها الايروسيل ٢٠٠ والسيليكا الحيوية حيث كانت قيم التركيز القاتل ل ٥٠% من الحشرات المختبرة بعد ٢٤ ساعة من المعاملة للسيليكا الكيميائية (٥٤،١ ، ٣٧،٠ ، ١٤،٠) بخلاف الايروسيل ٢٠٠ (٦٥،٢ ، ٤٢،٠ ، ١٥،٠) والسيليكا الحيوية حيث كان (٣٥،٧ ، ٩١،٦ ، ٤٣،٢) جم/ كجم حبوب بالنسبة لخنفساء الدقيق المتشابهة ، ثاقبة الحبوب الصغري ثم خنفساء اللوبيا علي الترتيب. كان لكل صور السيليكا المستخدة تأثيرا عائقا علي الاطوار الداخلية لخنفساء اللوبيا عند كل التركيزات المستخدمة وأوضحت النتائج ايضا ان طور البيضة كان اكثر حساسية مقارنة باليرقة والعذراء وانخفضت نسبة خروج الحشرات والفقد في وزن الحبوب مع كل التركيزات المستخدمة، ونتيجة لذلك اوضحت الدراسة الحالية ان الصور الثلاثة المستخدمة من السيليكا هي مواد مبشرة لمكافحة الحشرات المختبرة كبدائل آمنة للمبيدات الكيميائية المصنعة.