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Performance of Some Soil Minerals and Potassium Silicate on Peach Fruit Fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) under Laboratory Conditions

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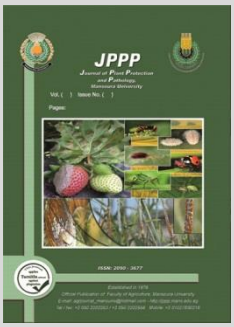

ABSTRACT

The toxic & repellent effects of some different silicon sources in powder and liquid forms were assayed on peach fruit fly *Bactrocera zonata* for 3 days under laboratory conditions. In a toxicity study against adult and pupa stages, the results indicated that a potent effect of diatom, kaolin, aglive Si 300 and bentonite in powder form of silicon with corrected mortality from 40 to 100 %**,** respectively. In a liquid form, potassium silicate formulations had toxic effect in different corrected mortality percentage from 55.7 to 100%. Potassium salt, (boiled lime & sulfur) and palmito formulation gave highly toxic effects as a traditional treatment. In a repellency percentage, the results indicated that palmito, kaolin, bentonite, boiled lime & sulfur and kaolinated potassium silicate showed the highest repellent action as compared with other treatments. With different concentrations, boiled lime & sulfur treatment gave the most repellency percentage against adult of peach fruit fly with 80 to 33% after 1-6hrs. from treatment, these concentrations the percentage of repellency from 53.0 –100.0% after 24hrs. from treatment. Kaolinated potassium silicate showed the second order in repellent action against adults which gave PR% ranged from 35 to 65% and 55 to 95% repellency after 1-6 & 24hrs., respectively at different concentrations. Si El-Ghanem treatment showed the least effect with PR% from 30 to 10% after 1-6hrs. and 40 to 15% after 24hrs. The silicon studied could provide suitable alternatives into IPM programs.

Keywords; *Bactrocera*,Toxicity, Repellent, Minerals, Silicon

INTRODUCTION

Tephritid fruit flies of the genus *Bactrocera* have particularly caused great concern because of the magnitude of damage they inflict. The fruit fly causes losses in the crop and reduced fruit quantity and quality. (Pangihutan *et al*., 2022). Different species of family Tephritidae were found in Egypt. Recorded *Bactrocera zonata* (saunder) (Diptera: Tephritidae) as new fruit pest attacking a lot of fruit species in Egypt including mango, guava, peach, apricot, apple, citrus as well as some vegetable crops (Joomaye & Price, 2000 and White, 2000). Annual financial losses associated with fruit flies are estimated at 320 million Euros in the Middle East and 190 million Euros in Egypt (OEPP/EPPO, 2005 & 2010). The geological distribution and abundance of *B. zonata* were attributed mainly to favorable climatic conditions and accessibility (Delrio and Cocco, 2010) Female flies lay their eggs under the skin of the fruit and the young reproduce and develop inside the fruit. Mated female flies lay their eggs on aged natural products, followed by midges and other helpful microorganisms that feed on the mash of the natural product, resulting in spoilage. The splashes caused by the puppies vary from the unsightly appearance due to egg punctures leading to reduced attractiveness and the shedding of the natural product leading to reduced yield. Administration costs in response to damage are high due to excessive invasions (Kumbirai *et al*., 2020).

Silicon is a relatively inert element that occurs freely in nature. It is present in plants in the oxidized form, silicon dioxide (SiO_2), commonly called silica. Silica is mainly present in the form of quartz, diatoms, kaolin, bentonite, magnesium aluminum silicate and potassium silicate. Minerals are widely used as essential raw materials or additives in the production of cement, paint, ceramics, pharmaceuticals, cosmetics and agrochemicals (Manjaiah *et al*., 2019). Minerals can be used as the fertilizers and pesticides production. Fertilisers and insecticides can be made using minerals. In the pesticide industry, minerals are transporters. (Yusoff *et al*., 2016). Minerals were a highly efficient chemicals to keep the oriental fruit fly invasion under control (Pangihutan and associates, 2022). In the management of plant diseases, minerals are also listed as fungicides (Jaramillo et al., 2017). Kaolin has the ability to suppress several pests as the olive fly (Mozhdehi & Kayhanian, 2014 and Ali, 2016) as well as the Mediterranean fruit fly (*Ceratitis capitata* (Wiedemann)) (Campos & Martínez, 2013), *Elathaame*, or *ligranat* Klug and the fruit fly *Drosophila suzukii* Mats (Lepidoptera: Lycanidae) (Ali, 2017). In 2019 Knapp *et al*., said that kaolin particles are resistant to extreme heat and sunshine (Braham and others, 2007).

Kaolin can be used to prevent the invasion of pests, such as the leaf miners, the Persian summer minus aphid and the cotton army (Huber) (Alamo). Despite this, little is known about the use of kaolin to reduce oriental fly infestations. Minerals have a very important economic impact in crop protection. Mineral-based pesticides have advantages over other biopesticides, in terms of raw material availability and

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natural stability and could stop oriental fruit flies from laying eggs on fruit or to minimize damage. Research in the past has demonstrated that fruit flies can be successfully deterred from apple and mango trees by using kaolin (Villanueva & Walgenbach, 2007 and Ghada, 2021). But some people are unaware of how effectively minerals stop fruit flies from visiting, depositing their eggs, and invading their host fruits. Other minerals that were safe for the environment and people to use were used in this investigation. Additionally, as was previously noted for bentonite (El-Aziz, 2013), they have the ability to control insects. Unicellular algae known as diatoms can be found in freshwater and marine settings. In the water's surface layers, a wide variety of diatom species can be seen floating (Soubeih *et al*., 2017).

Diatoms are utilized in a wide range of products, including toothpaste, fertilizers, polishes, catalyst carriers, and porcelain (Mann and Stickle, 1997). Diatoms have been studied for their potential in pest management due to their high silica content (85%), which is primarily made up of amorphous silica (SiO_2) (Laing *et al*., 2006). Silicon provides stiffness, strength, and resistance against pests and diseases. It also reduces transportation rate, improves water economy, lessens the negative impacts of abiotic stresses, and increases crop yields in all situations (Vasanthi *et al*., 2014). Silicon is an ally useful to agronomy. When it comes to how diatoms affect an insect's exoskeleton, diatomaceous earth—powdered remains of fossilized diatoms with minuscule, sharp protrusions that cause serious harm to crawling insects—is a more effective insecticide than diatoms (Sarwar, 2016). Diatoms, which are manufacture commercially by a milling process, yield a glass-like product that is employed as a dust or spray, according to research by (Crooks and Prentice 2011). In addition to making insects less tolerant to environmental conditions, the product has the ability to puncture or scratch the exoskeleton of insects and release chemicals from diatom cells onto plant leaves (Linker *et al*., 2000).

The aim of this study was to assay the effectiveness of some minerals and potassium silicate against peach fruit fly infestations under laboratory conditions.

MATERIALS AND METHODS

A. Silicon Sources

In this study, we used different silicon sources in two groups. The first one was powder group that were kaolin, bentonite, attapulgite (Agliv Si 300) and Diatomaceous Earth (Diatom) that were naturel soil sources. The second was liquid group, potassium silicate that had three sources of liquid silicon. While, the source (potassium silicate) of the first was from sand (Si El-Ghanem), the second was from kaolin mineral (kaolinated potassium silicate) and the third (silica ke) was from chemical manufacture. The previous materials were compared with the standard natural insecticide as Palmito and untraditional material as (boiled lime & sulfur and potassium salt) (Ali *et al*., 2021 and 2022). Material sources are listed in Table 1 as follows:

Table 1. Different silicon formulations

	Name	Case	Source	Structure
1	Kaolin	Powder clay	Investment Petroleum Group IPG inc	Aluminum Silicate
2	Bentonite	Powder clay	Green Way Company	Aluminum Silicate (Calcium)
4	Diatom	Powder	Green Way Company	Diatom
8	Potassium salt	Powder	Green Way Co.	Potassium
3	Aglev Si 300	Powder clay	Geohellas company	Magnesium Aluminum Silicate
5	Si El-Ghanem	Liquid	Abo Ghanema company	Potassium silicate
6	Silica Ke	Liquid	Techno Green	Potassium silicate
7	Kaolinated Potassium silicate	Liquid	Investment Petroleum Group IPG inc	potassium silicate + kaolin
9	Palmito	Liquid	El-Masria for fertilizers	Some plant extracts
10	Boiled lime & sulfur	Liquid	Green Way Co.	lime & sulfur

B. Rearing of peach fruit fly

Laboratory stock culture of peach fruit fly *Bctrocera zonata* (Saunders) (Diptera: Tephritidae) *was* started from samples of infested fruits. Eggs of the Laboratory peach fruit fly, *Bactrocera zonata* (were obtained from Plant Protection Research Institute and kept in the fruit fly Laboratory, Agricultural Research Center for several generations without exposure to any insecticide under conditions of (25±2°C, 60±5% R.H and photoperiod of 14 L: 10 D). The eggs were scattered on surface of the artificial diet according to (Tanaka *et al.*, 1969) and was modified by (Shehata *et al.*, 2006) which was placed in plastic trays of (20 x 10 x 8cm) until larval pupation. Pupae were separated and kept in cages until emergence of flies. Adult flies were fed on sugar and fortified protein hydrolysate. The fruits were kept under laboratory conditions of 25±3°C and 70% RH. inside a wooden cage (0.7 X 0.5 X 2.0 m) contained sand for mature maggots pupation. Pupae were collected and transferred to the adult rearing cages with wooden frames, supplied with mesh screen from all sides except one with muslin to allow aeration the emerging females to lay eggs. Fortified enzymatic yeast hydrolysate and sugar, cotton wick saturated with water (in a plastic ban) were introduced for adult feeding. The laboratory rearing conditions were adjusted at 25±1°C, 65%±5 RH and 12:12 LD photoperiod from artificial light supplement necessary for mating behavior (Afia, 2007). The deposited eggs of *B. zonata* were received in an egg receptacle placed in the cage (a yellow plastic glass with fin holes in its sides and smeared internally with guava juice). Eggs of *B. zonata* were daily collected and' transferred after 2 hours to a plastic tray containing the larva wheat bran diet. Larvae were maintained on bran diet described by Tanaka *et al.,* 1969 and Awadallah, (1978) for rearing larvae of *Ceratitis capitata* with a modification in the weight of ingredients to be used for rearing of *B. zonata* that was cleared in Table 2 (Afia, 2007).

Table 2. Ingredients of artificial diet of larvae of the peach fruit fly, *Bactrocera zonata* (Saund).

Ingredient	Quantity (gm)
'Wheat bran	990
Brewer's yeast	247.50
Sugar	247.50
Sodium benzoate	9.9
Citric acid	9.9
Tap water (ml)	1500

These ingredients were homogenized for 2-3 minutes to prepare a paste medium of an acidic pH (3-4). Media were put in a small plastic tray (20 X 14 cm). Each tray contains 250-gram diet) and covered with muslin, then placed in a big plastic cages (40 X 25 XI5 cm) containing a layer of clean sand for maggots pupation. Sand was sieved for collecting of pupae which placed in the adult cage.

C. Bioassay of some silicon formulations against peach fruit fly *Bactrocera zonata*

1. Toxicity test on adults of peach fruit fly

The toxic effect of silicon materials on adult flies of *B. zonata* tested by using residual thin film technique (Ali, 1999, Reda *et al.,* 2016). Three ml of the desired tested concentration were evenly spread on a petri-dish surface (9 cm in diameter). The solvent was allowed to evaporate leaving a thin film of the used materials. Ten adults newly emerged (3 days age) were put in each petri dish from treatment. Three days-old male and female flies adult of peach fruit fly were exposed to the thin film for three days. With serial concentrations; 100, 80, 60, 40 & 20% of the most effective silicon formulations. Each concentration was replicated 5 times. The control treatment was dipped in distilled water. Mortality counts were calculated for each 24 hours for the six days exposure period until the adults die. The mortality percentage was corrected for the natural mortality according to Abbott's formula (Abbott, 1925). The mot powerful compound was used as a standard for comparing tested material efficiencies using the toxicity index ((Hamouda, *et al*., 2022) and (Gaber and Nasr, 2020)).

$$\text{Toxicity index} = \frac{LC_{50} \text{ of the most powerful compound}}{LC_{50} \text{ of the tested material}} \times 100$$

2 Toxicity test on pupa stage of peach fruit fly

The efficacy of some silicon formulations against 1-day old pupae of *B. zonata* was evaluated by sandy soil method. Sand was sieved and put in plastic cups (50g cup-1). Plastic cups, (6 cm diameter and 8 cm height) lined with 1 cm height of sterile sand with 14% moisture were used. Four replicates were used of each treatment, it was selected for the final experiments, 7.5 ml of water (required amount for saturation) were added in each cup. Following that, the sands were properly stirred with a glass rod to mix the solution homogenously. Then 10 pupa of 3-days old were confined and buried into sand in each cup. The cups were covered with muslin clothes which tightly secured with rubber bands and left under the above mentioned laboratory conditions till adult emergence. Control experiments using soil saturated with water only also carried out for comparison and correcting mortalities in treatments as previously mentioned in surface contact treatment. After certain days, the numbers of emerging adults from pupa were counted for each cup (Marwa *et al.,* 2015, Sahadat and Khalequzzaman, 2018). The adult emergence was record after 15 days from treatments under laboratory conditions.

D. Repellent test on adults of peach fruit fly

New adults of peach fruit fly had emerged and after one day, forty pairs of newly emerged adults (20 male and 20 female) were selected at randomly and kept in a small transparent plastic cage (25x15x15 cm), provided with water, protein hydrolysate and sugar. After mating, females started oviposition after 15 days. The experiment was started with the prepared solutions and concentrations of powder and liquid silicon forms. With serial concentrations; 100, 80, 60, 40 & 20% of the most effective silicon formulations. Fresh healthy guava fruits were dipped with different concentrations of silicon formulations and dried at room temperature for two hours. Treated and untreated guava fruits (2 treated fruits and 2 untreated fruits) were offered to 5 pairs of 10 peach fruit flies in plastic box (measuring 15cm Radius ×25cm height) for 24hrs days in a free choice bioassay for settling and oviposition response (Rehman *et al*., 2009). Number of fruit flies settled on treated and untreated guava fruits was counted. The experiments were replicated three times. The percentage repellency (PR%) was calculated according to (Ali, 1999) :.

$$PR\ \% = \frac{(N - C)}{C} \times 100$$

Where : **N = the number of insects present in the control half.**
C = half the number of total insects present.
Positive values (+) expressed repellency and negative values (-) attractancy.
PR% = Percent repellency values were assigned repellency classes by using the following scale : classes I, II, III, IV and V designated percent repellency values of < 0 - 20, 20.1 - 40, 40.1 - 60, 60.1 - 80 and 80.1 - 100, respectively.

RESULTS AND DISCUSSION

Results

A. Toxic effect of some silicon formulations on *Bactrocera zonata*.

The potential effects of some different silicon sources (powder and liquid forms) compared with potassium salt, Palmito formulation and boiled lime & sulfur were studied on the attacks of adult peach fruit fly *Bactrocera zonata* through 3 days exposure period under laboratory conditions. The effects against peach fruit fly insect increased as exposure time after treatment increased.

Toxic effects on adult of *Bactrocera zonata*

Toxic effects of silicon powder formulations against adult of *Bactrocera zonata*

The toxic effect of four minerals, (diatom, kaolin, bentonite and Agliv Si 300) on lab peach fruit fly, *Bactrocera zonata* adults (3-days old) by using residual thin film method was shown in Table 3. The diatom, potassium salt and palmito commercial formulation treatments caused the highest percentages of fly's mortality (100%). Followed by Kaolin and Agliv Si 300 minerals their corrected mortality percentage was 78.7 & 74.5% after 3 days exposure time. Followed by Bentonite mineral that showed the least mortality percentage with 51.1 % for the same exposure period.

Table 3. Effect of silicon powder formulations on corrected mortality percentage of peach fruit fly, *Bactrocera zonata* with the residual film technique.

Treatments	Exposure time (Days) % Corrected Mortality		
	1	2	3
Diatom	100.0	100.0	100.0
Kaolin	24.5	39.6	78.7
Aglev Si 300	26.5	29.2	74.5
Bentonite	30.6	43.8	51.1
Poassuim salt	100.0	100.0	100.0
Palmito	100.0	100.0	100.0

Toxicity lines and LC_{50} values for some powder silicon formulations against adult of *Bactrocera zonata*

Data in table (4) demonstrated that palmito, potassium salt, diatom, kaolin and aglev Si 300 showed the

highest toxicity against adult of *Bactrocera zonata*, so more details must be studied to calculate the lethal concentrations (LC_{50}). The lethal concentrations (LC_{50}) along are presented in Table 4. Based on the toxic activity, Palmito and potassium salt formulations showed the most toxic (LC_{50}= 20.2 & 21.0) mg/ml to the adults followed by diatom and kaolin with LC_{50} 39.7 & 66.2 mg/ml but agliv Si 300 and bentonite were the least toxic (LC_{50}= 74.7 & 161.7mg/ml). Regarding to the toxicity index, at LC_{50} it's clear that potassium salt, diatom, kaolin and Aglive Si 300 were about 96.2, 50.9, 30.5 & 27.0% for LC_{50}, respectively. The 4th compound (bentonite) had weak toxicity index on adult of peach fruit fly with 12.5 mg/ml.

Table 4. Effect of silicon powder formulations on LC_{50} corrected mortality percentage of peach fruit fly, *Bactrocera zonata* with the residual film technique.

Treatments	Exposure time (Days)						Toxicity Index for LC_{50} after 3 days
	1		2		3		
	LC_{50}	P	LC_{50}	P	LC_{50}	P	
Diatom	52.5	3.2	46.7	2.4	39.7	2.5	50.9
Kaolin	184.8	1.7	122.7	1.6	66.2	2.3	30.5
Aglev Si 300	188.2	1.6	140.7	2.6	74.7	2.4	27.0
Bentonite	169.5	2.1	108.7	2.2	161.7	1.8	12.5
Potassium salt	33.2	2.4	26.3	1.5	21.0	2.1	96.2
Palmito	35.5	2.3	29.0	1.8	20.2	1.9	100

***Toxicity index = LC_{50} (mg/ml) of the most powerful compound x 100 / LC_{50} (mg/ml) of the tested sample x 100**

Toxic effects of silicon liquid formulations against adult of *Bactrocera zonata*

The toxicity of silicon liquid formulations against the adult stage of susceptible strain of *Bactrocera zonata* is demonstrated in Table (5). Data clearly indicated that the order of the efficiency of the tested of silicon liquid formulations based on corrected mortality percentage were (boiled lime & sulfur), kaolinated potassium silicate, palmito and Si-El Ghanem, formulations, However the highest corrected mortality gave 100% against peach fruit fly after 3 days exposure time. Silica Ke was the least effect with 83.0 % corrected mortality after three days from exposure.

Table 5. Effect of silicon liquid formulations on corrected mortality percentage of peach fruit fly, *Bactrocera zonata* with the residual film technique.

Treatments	Exposure time (Days) % Corrected Mortality		
	1	2	3
Silica Ke	26.5	60.4	83.0
Boiled lime & sulfur	100.0	100.0	100.0
Kaolinated Potassium silicate	100.0	100.0	100.0
Si El-Ghanem	30.6	85.4	100.0
Palmito	100.0	100.0	100.0

Toxicity lines and LC_{50} values for some liquid silicon formulations against adult of *Bactrocera zonata*

The contact residual toxicity of the silicon liquid formulations showed varying degrees of toxicities. Table (6) shows LC_{50} and toxicity index of the tested formulations against adult of *B. zonata*. The gradation of toxicity of silicon liquid formulations against adult of *B. zonata* is kaolinated potassium silicate > boiled lime & sulfur, > Si El-Ghanem proved to be the most effective among the treatments used. The obtained results revealed that kaolinated potassium silicate, Palmito and boiled lime & sulfur were the most potent compound at LC_{50} (19.0, 20.0 and 20.2 mg/ml, respectively) surpassing the other used treatments. Si El-Ghanem alternated third orders at LC_{50} (22.6). The efficiency of Silica ke was much more lower than that of the above mentioned treatments recording high values of LC_{50} against the adult of *B. zonata* of 70.0 mg/ml, successively. Toxicity index of the five used compounds were 100.0, 95.0, 94.0, 84.1 and 27.1 for kaolinated potassium silicate, Palmito, boiled lime & sulfur, Si El-Ghanem and Silica Ke, respectively that compared with kaolinated potassium silicate formulation with LC_{50} 19.0.

Table 6. Effect of silicon liquid formulations on LC_{50} corrected mortality percentage of peach fruit fly, *Bactrocera zonata* with the residual film technique.

Treatments	Exposure time (Days) % Corrected Mortality						Toxicity Index for LC_{50} after 3 days
	1		2		3		
	LC_{50}	P	LC_{50}	P	LC_{50}	P	
Silica Ke	189.4	1.6	120.5		70.0	2.6	27.1
Boiled lime & sulfur	32.0	1.2	25.3	1.2	20.0	0.9	95.0
Kaolinated Potassium Silicate	34.6	1.1	24.2	1.3	19.0	1.6	100.0
Si El-Ghanem	170.6	2.1	75.0	2.8	22.6	1.1	84.1
Palmito	35.5	1.2	29.0	1.6	20.2	1.4	94.0

Toxicity index = LC_{50} (mg/ml) of the most powerful compound x 100 / LC_{50} (mg/ml) of the tested sample x 100A.2

Toxic effects on pupa stage of *Bactrocera zonata*

In the present study, some silicon sources as biopesticides were evaluated under laboratory conditions against pupae stage of peach fruit fly. The results were displayed as follows:

Toxic effects of silicon powder formulations against pupa stage of *Bactrocera zonata*

The fatal effect of the tested minerals against 1-day old pupae of *B. zonata* in treated sandy soil is given in Table (7). The corrected mortality percentage of treatments was evaluated against the pupa of peach fruit fly.

Table 7. Toxicity of some silicon powder formulations on pupae of *B. zonata* when mixed with treated soil

Treatments	% Mortality	LC_{50} mg/ml,	Slope	Toxicity index* at LC_{50}
Diatom	66.5	74.6	1.7	60.6
Kaolin	60.6	84.5	1.8	53.5
Aglev Si 300	50.7	119.1	1.5	38.0
Bentonite	40.4	208.6	1.2	21.7
Potassuim salt	80.2	57.9	1.7	78.1
Palmito	90.0	45.2	2.0	100

Toxicity index = LC_{50} (mg/ml) of the most powerful compound x 100 / LC_{50} (mg/ml) of the tested sample x 100

The results showed that Palmito and potassium salt formulations showed the best effect against the pupa with 90.0 & 80.2% corrected mortality. Diatom, kaolin and Aglive Si 300 had a potential effect more than 50.0% with corrected mortality 66.5, 60.6 & 50.7% respectively against pupa of peach fruit fly. Otherwise, the bentonite treatment indicated the least effect with 40.4% corrected mortality against pupae of *B. zonata*. With respect to LC_{50} values, Palmito and potassium salt were the most potent compounds (45.2 & 57.9 mg/ml) following by diatom, kaolin and Aglive Si 300 with LC_{50} values 74.6, 84.5 and 119.1 mg/ml,

while bentonite treatment was the least one recording LC_{50} 208.6 mg/ml against 1-day old pupae of *B. zonata*. Regarding to the toxicity index, at LC_{50} it's clear that Palito, potassium salt, diatom, kaolin and Aglive Si 300 were about 100.0, 78.1, 60.6, 53.5 and 38.0%, respectively. The bentonite had weak toxicity index (21.7%) on pupae of peach fruit fly.

Toxic effects of silicon liquid formulations against pupa stage of *Bactrocera zonata*

According to the corrected mortality values in Table (8), Palmito, kaolinated potassium silicate, (boiled lime & sulfur) were the most potent materials with mortality percentage more than 80% (90.0, 88.3 & 87.8) followed by Si El Ghanem and Silica Ke formulations with corrected mortality percentage 68.0 and 55.7% respectively against pupa of peach fruit fly.

In addition to the toxicity of silicon liquid formulations, toxicities of six formulations on pupae of peach fruit fly are listed in Table (8). Palmito formulation was the most toxic (LC_{50} = 45.2 mg/ml) to pupa, followed by kaolineted potassium silicate (LC_{50} = 52.3 mg/ml), (boiled lime & sulfur) (LC_{50} = 54.1 mg/ml), Si El-Ghanem (LC_{50} = 79.8 mg/ml) and Silica Ke (LC50 = 121.7 mg/ml) against 1-day old pupae of peach fruit fly. Regarding to the toxicity index, at LC_{50} it's clear that Palmito, kaolinated potassium silicate, (boiled lime & sulfur), potassium salt, Silica Ke and Si El-Ghanem were about (100, 86.4, 83.5, 78.1, 56.6 & 37.1%), respectively against 1-day old pupae of peach fruit fly.

Table 8. Toxicity of some silicon liquid formulations on pupae of *B. zonata* when mixed with treated soil

Treatments	% Corrected Mortality	LC_{50} mg/ml	Slope	Toxicity index* at LC_{50}
Potassium salt	80.2	57.9	1.7	78.1
Silica Ke	55.7	121.7	1.2	56.6
Boiled lime & sulfur	87.8	54.1	1.7	83.5
Kaolinated Potassium silicate	88.3	52.3	1.6	86.4
Si El-Ghanem	68.0	79.8	1.2	37.1
Palmito	90.0	45.2	2.0	100

Toxicity index = LC_{50} (mg/ml) of the most powerful compound x 100 / LC_{50} (mg/ml) of the tested sample x 100

B. Repellent effect of some silicon formulations on *Bactrocera zonata*.

Repellent effects of silicon powder formulations against adult stage of *Bactrocera zonata*

The repellency of four minerals as a source of silicon powder products was tested against the adults of *B. zonata* under the laboratory conditions. The data presented in Table (9) represent average repellency action (average from 1 to 6 hours and after 24 hours) of silicon treatments against the adults of the peach fruit fly. Palmito formulation treatment showed strong repellent effects after 6 and 24 hours. Its average repellency percentages (PR%) were 96.7 and 100.0 % (class V), respectively. Kaolin and bentonite minerals had a moderate repellent effect (56.7 and 47.8) (class III) after six hours which increased with time to be 89.0 and 86.7% (class V) after 24 hours from exposure. Diatom gave acceptable repellent effect with 37.8 and 66.7 % (class II & IV) after 6 and 24 hours, respectively against *B. zonata*. In the other hand, Aglive Si 300 had very weakly repellent after 6 and 24 hours with repellency percentages (PR %) 11.1 and 33.3 (class I & II) after 6 and 24 hours.

Table 9. Repellent effect of silicon powder formulations on peach fruit fly, *Bactrocera zonata*.

Treatments	Exposure time (hours) % PR			
	1-6hrs.	Class	24hrs.	Class
Palmito	96.7	V	100.0	V
Kaolin	56.7	III	89.0	V
Bentonite	47.8	III	86.7	V
Diatom	37.8	II	66.7	IV
Aglev Si 300	11.1	I	33.3	II
Potassium salt	7.3	I	15.7	I

PR% = Percent repellency values were assigned repellency classes by using the following scale: classes I, II, III, IV and V designated percent repellency values of < 0 - 20, 20.1 - 40, 40.1 - 60, 60.1 - 80 and 80.1 - 100, respectively.

Repellent effects of silicon liquid formulations against adult stage of *Bactrocera zonata*

Data given in Table (10) showed the repellency actions of the commercial products of silicon liquid formulations against adult of peach fruit fly. In the Palmito formulation, boiled lime & sulfur and kaolinated potassium silicate gave the most repellent action with (96.7, 81.5 & 65.6 %) and (100.0, 100.0 & 92.6 %) repellency class (V, V & IV) and (V, V & V) after 1-6 and 24 hrs., respectively. Si El-Ghanem and Silica Ke were the least effective (class II & I) with repellent percentage (28.3 & 10.2%) and (37.9 & 22.5%) after 1-6 and 24 hours.

Table 10. Repellent effect of silicon liquid formulations on peach fruit fly, *Bactrocera zonata*.

Treatments	Exposure time (hours) % PR			
	1-6	Class	24	Class
Silica Ke	10.2	I	22.5	II
Boiled lime & sulfur	81.8	V	100.0	V
Kaolinated potassium silicate	65.6	IV	92.6	V
Si El-Ghanem	28.3	II	37.9	II
Palmito	96.7	V	100.0	V

PR% = Percent repellency values were assigned repellency classes by using the following scale: classes I, II, III, IV and V designated percent repellency values of < 0 - 20, 20.1 - 40, 40.1 - 60, 60.1 - 80 and 80.1 - 100, respectively.

The previous results indicated that Palmito, kaolin, bentonite, boiled lime & sulfur and kaolinated potassium silicate showed the highest repellent action. For detailed studies a series of concentrations 100, 80, 60, 40 and 20 % were prepared to calculate the repellency percentages.

Repellent effect of serial concentrations of silicon sources against on adults of peach fruit fly

Repellent effect of serial concentrations of silicon powder sources against on adults of peach fruit fly

The data presented in Table (11) showed average repellency action (average from 1-6 hrs. and after 24 hours) of kaolin, bentonite and diatom minerals compared with Palmito formulation as plant extract formulation against adult of *B. zonata* on guava fruits. The highest repellency of Palmito formulation were observed (95.0 & 100.0%) at 100.0 & 80.0% concentrations followed by 80.0 & 70.0% after 1-6 hrs. and 95 & 85% after 24hrs. at 60.0 & 40.0% concentrations of Palmito formulation where as the lowest were observed (30 & 33.0%) at 20% concentration against adults of *B. zonata*. Bentonite and kaolin showed strong repellent effects after 1-6 and 24 hrs. Their average repellency percentages (PR%) ranged from 50 – 25% repellency (class-IV) after 1-6 hrs. and increased to 90- 50% repellency after 24 hrs., respectively at 100, 80, 60, 40 &

20% concentrations. On the other hand the diatom had moderate repellency action after 1-6 and 24 hrs. with PR % were 40.0 and 21.0 % after 1-6 hrs. and 65-28%, (class V) after 24 hrs., respectively at 100, 80, 60, 40 & 20% concentrations. Ranking action effects in the five classes showed that, the repellency effects of the tested minerals ranged between class I and class IV depending on the tested concentration and exposure time.

Table 11. Repellent of serial concentrations of silicon powder formulations on adults of peach fruit fly

Treatments	Concentrations	Exposure time (hours) % PR			
		1-6hrs.	Class	24hrs.	Class
Palmito	100%	95.0	V	100.0	V
	80%	95.0	V	100.0	V
	60%	80.0	IV	95.0	V
	40%	70.0	IV	85.0	V
	20%	30.0	II	33.0	II
Kaolin	100%	56.0	III	85.0	V
	80%	50.0	III	83.0	V
	60%	45.0	III	78.0	IV
	40%	30.0	II	60.0	III
	20%	25.0	II	55.0	III
Bentonite	100%	50.0	III	90.0	V
	80%	50.0	III	90.0	V
	60%	43.0	III	85.0	V
	40%	32.0	II	60.0	III
	20%	26.0	II	50.0	III
Diatom	100%	40.0	II	65.0	IV
	80%	37.0	II	65.0	IV
	60%	35.0	II	55.0	III
	40%	27.0	II	50.0	III
	20%	21.0	II	28.0	II

PR% = Percent repellency values were assigned repellency classes by using the following scale: classes I, II, III, IV and V designated percent repellency values of < 0 - 20, 20.1 - 40, 40.1 - 60, 60.1 - 80 and 80.1 - 100, respectively.

Repellent effect of serial concentrations of silicon liquid sources against adult of peach fruit fly

Data presented in Table (12) declared that boiled lime & sulfur treatment gave the most repellency percentage against adults of peach fruit fly with 80 to 33% after 1-6hrs. that increased to 100.0 – 53.0% after 24hrs., respectively with the five concentrations.

Table 12. Repellent effect of serial concentrations of silicon liquid formulations on adults of peach fruit fly

Treatments	Concentrations	Exposure time (hours) % PR			
		1-6hrs.	Class	24hrs.	Class
Boiled lime & sulfur	100%	80.0	IV	100.0	V
	80%	75.0	IV	100.0	V
	60%	70.0	IV	90.0	V
	40%	55.0	III	70.0	IV
	20%	33.0	II	53.0	IV
Kaolinated Potassium	100%	65.0	III	95.0	V
	80%	64.0	III	95.0	V
	60%	62.0	III	90.0	V
	40%	54.0	III	75.0	IV
	20%	35.0	II	55.0	III
Si El-Ghanem	100%	30.0	II	40.0	III
	80%	27.0	II	38.0	II
	60%	25.0	II	35.0	II
	40%	18.0	I	20.0	I
	20%	10.0	I	15.0	I

PR% = Percent repellency values were assigned repellency classes by using the following scale: classes I, II, III, IV and V designated percent repellency values of < 0 - 20, 20.1 - 40, 40.1 - 60, 60.1 - 80 and 80.1 - 100, respectively.

Kaolinated potassium silicate was the second effect material in repellent action against adult of peach fruit fly which gave PR% ranged from 65 to 35% and 95 to 55% repellency after 1-6hrs. & 24hrs., respectively with different concentrations. Si El-Ghanem treatment showed the least effect with PR% from 30 to 10% at 1-6hrs. and 40 to 15% after 24hrs.

Discussion

Biotic stress includes insects caused damage to other living organisms,. Besides the global agricultural potency. However, pests and pathogens have become tolerant to the use of conventional methods to improve agricultural production. The entomotoxic effects of silica structures were explored against some insects by utilizing the leaf dipping technique bioassay protocols (Ali *et al*., 2021). Yusoff *et al*., 2016 said that minerals are one of the raw materials used in agriculture to make pesticides and were used as carriers in manufacturing of pesticides. Using particle film to avoid fruit fly and prevent egg-laying is a primary strategy, though typically confined to kaolin as the main option. Propolis, pulverized rock, kaolin, the combination of propolis and pulverized rock, the combination of propolis and kaolin, consisting of particle films, are effective in deterring *Bactrocera oleae* from egg laying. The combination of rock powder and propolis led to a decrease in *B. oleae* infestation. Furthermore, the combination of kaolin and propolis showed the most favorable outcomes compared to all other treatments. When combined with propolis, particle films displayed increased defense against *B. oleae* compared to when used independently, indicating a synergistic impact, and highlighting propolis' intriguing function as an enhancer (Daher *et al*., 2023).

Silicon effectiveness in controlling peach fruit fly, *Bactrocera zonata* is poorly understood. In the current investigation, however, we found that some silicon formulations could reduce the attack of peach fruit fly under laboratory conditions. In a laboratory test, toxicity and repellency effects were assayed to four minerals (diatom, kaolin, bentonite, aglive Si 300) as a source of silicon in powder form and three silicon liquid sources of potassium silicate (kaolinated potassium silicate, Si El-Ghanem and Silica ke) compared with plant extract formulation (palmito), potassium salt and Liquid boil & lime of sulphur in addition to control treatment in different concentration (100, 80, 60, 40 & 20%) against adult and pupa stages of peach fruit fly, *Bactrocera zonata*.

In a toxicity study against adult and pupa stages of peach fruit fly after 3 days from exposure time, the results indicated that a potent effect of diatom, kaolin, aglive Si 300 and bentonite in a powder forms of silicon with corrected mortality from 40 to 100 %, respectively. In a liquid form, potassium silicate formulations had a toxic effects in different corrected mortality percentage from 55.7 to 100%. Potassium salt, (boiled and sculpture) and palmito formulation gave highly toxic effects as a traditional treatments. Their lethal concentrations (LC_{50}) gave variations in their values depends on the concentrations and the exposure time. The results obtained in this study were agreed with other studies that carried out on different insects species ; for example, Ali *et al*., 2021 and 2022 observed that Kaolin, Diatom, Aglive Si 300, kaolinated potassium silicate, Silica Ke, Palmito and potassium salt formulations gave corrected mortality from 54.0 to 100% against adult

and preadult stage of mango shield scale insect *Milviscutulus Mangiferae* and adult female stage of the two-spotted spider mite *Tetranychus urticae*, after 3 days from exposure time under laboratory conditions. In even better agreement with our results, Ghada, 2021 conducted to evaluate mineral-organic compounds such as "kaolin" and calcium carbonate Also, kaolin was more effective following calcium carbonate compared to Malathion as the common insecticide. Constructed kaolin, forming a particle film on fruits surface as a barrier to protect them from putting eggs with *Bactrocera zonata* female,. Similarly, like similar compounds used for pest control Also, Pangihutan *et al*., (2022) said that Kaolin has been used to control Mediterranean fruit flies, *Ceratitis capitata*, olive fruit fly, *Bactrocera oleae* (Mozhdehi and Kayhanian, 2014), cherry fruit fly, *Rhagoletis cerasi* L (Mezőfi *et al*., 2018), *Anastrepha fraterculus* (Ourique *et al*., 2019), and spotted wing drosophila fruit fly, *Drosophila suzukii* Mats. (Knapp *et al*., 2019). Kaolin can also be used to suppress the attack of other insect pests such as leafminer *Liriomyza huidobrensis* (Blanchard), aphid *Myzus persicae Sulzer* (Soubeih, *et al*, 2017), boll weevil, *Anthonomus grandis* (Silva & Ramalho, 2013), leafhopper *Empoasca vitis* (Markó *et al*., 2008) and cotton bollworm, *Helicoverpa armigera* (Hübner) (Alavo *et al*., 2011). It is possible synergy between the biological control agent *Beauveria bassiana* (*Bb*) and potassium silicate (KSil) for the control of two spotted spider mite Gatarayiha *et al*., (2010).

In a repellency percentage (PR%) study against adult of peach fruit fly, The results indicated that palmito, kaolin, bentonite, boiled lime & sulfur and kaolinated potassium silicate showed the highest repellent action as compared with other treatments. In a series of concentrations 100, 80, 60, 40 and 20 % were prepared to calculate repellency percentages.

Boiled lime & sulfur treatment gave the most repellency percentage against adult of peach fruit fly with 80 to 33% after 1-6hrs. from treatment and increased to 53.0 – 100.0% after 24hrs., respectively with the five concentrations. Kaolinated potassium silicate showed the second effect in repellent action against adult of peach fruit fly which gave PR% ranged from 35 to65 % and 55 to 95% repellency after 1-6 & 24hrs.from treatment, respectively with different concentrations. Si El-Ghanem treatment was the least effect with PR% from 30 to 10% at 1-6hrs. and 40 to 15% after 24hrs. from treatment these potential repellency effects of powder or liquid formulations against peach fruit fly can be explained by reducing the number of peach fruit fly visiting the treated fruits. With reference to repellent effects of some minerals, Hidayat *et al*., 2019 demonstrated the Physical factors that hinder a fruit fly from finding its host fruits could be one of the processes through which minerals reduce the oriental fruit fly infestations. Fruit flies locate their host fruits by detecting the color, shape, and aroma of the fruits. However, after dipping chili fruits in a mineral suspension at a concentration of 2%, the color of the fruits did not alter significantly in this investigation. Therefore, it is possible if the reduced number of oriental fruit flies visiting the treated chili fruits is not related solely to the color of the treated chili fruits. In even better agreement with our results, Ali *et al*., (2022) showed that potassium salt was the best treatment for the rate of laying eggs of the two-spotted spider mite *Tetranychus urticae* at 100 % concentration. In general, silicon liquid formulations were more effective on the oviposition rate for treated females than silicon powder formulations. In egg incubation treatment, kaolin (100% conc.) gave the longest incubation period with an average (4.8 days), while the lowest average (3.4 days) was recorded with bentonite (75% conc.), which is the same rate as was found in the control. The best treatment for the egg hatch rate was bentonite (100% conc.), while the least effect was recorded with Kaolin (50% conc. Accordingly to the results of egg period, the best treatments were Si El-Ghanem (100% conc.), bentonite (100% conc.), bentonite (75% conc.) and aglive Si 300 (100% conc.). The best treatments of larva period were bentonite (100% conc.), aglev Si 300 (100% conc.), diatom (100% conc.) and diatom (75% conc.). The present study revealed that some silicon formulations, such as diatom, kaolin, aglive Si 300, Si El-Ghanem, kaolinated potassium silicate and potassium salt can be used alternatively as acaricides for potential mite management in integrated crop management. Pangihutan *et al*., 2022 said that some minerals could reduce the attack of fruit fly *Bactrocera. dorsalis* under laboratory conditions. Seven minerals (talc, bentonite, sulfur, dolomite, calcium oxide, calcium oxide, and calcium carbonate) significantly reduced the number of chili fruits infested by oriental fruit flies. The treatments with five minerals (talc, sulfur, calcium oxide, calcium hydroxide, and calcium carbonate) reduced the number of eggs in chili fruits. The three minerals (talc, bentonite, and calcium oxide) made oriental fruit fly not to visit chili fruits. Besides lowering the number of fruit flies visiting chili fruits. Minerals have insect control properties, as previously reported for bentonite (El-Aziz, 2013), calcium carbonate (Morsi, 2021), calcium hydroxide (Estrada-Aguilar *et al*., 2012), sulfur (Tacoli *et al*., 2020), talc and zeolite (Floros *et al*., 2018) and zinc oxide (Gutiérrez-Ramírez *et al*., 2021). We hypothesized that, in addition to kaolin, there would be other minerals (Aglive Si 300, potassium salt and diatom) effective against oriental fruit fly attacks. Also, Michal and Amnon, (2004) indicated in laboratory and field trials with fruits treated with the 'Surround WP' in nectarines, apples and persimmons indicated an almost a protection against attacks of the *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae). In laboratory trials with 'Sunsnow' nectarines, in a choice and no choice tests, female flies avoided landing on treated fruits and no infestations resulted. Caleca *et al*., (2010) said potential of kaolin in reducing investigation of *Bactrocera oleae* on olives and those of *Ceratitis capitata* on citrus fruits; in olive groves, the clays gave similar or better results than copper hydroxide. Bentonite AG/8W showed a significant reduction in punctures by *C. capitata*. Clays are very useful tools to control tephritid and other insects and are also environmentally friendly.

CONCLUSION

Silicon treatments used in this study showed satisfactory toxicity and repellent inhibiting results against adults and pupa of peach fruit flies. The highest cumulative average scores of repellency and corrected mortality percentage (%) was observed. In case of some powder and liquid formulations of silicon forms of Diatom , kaolin, aglive Si 300 , bentonite kaolinated potassium silicate, Si El-Ghanem, palmito, (boiled & Sulpher) and potassium salt gave a potential against adults and pupa of peach fruit flies after three days exposure time. The silicon studied could provide

suitable alternatives into IPM programs. The field study must be done in the future studies in different pests on many crops.

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فاعليه بعض معادن التربه وسيليكات البوتاسيوم ضد ذبابه الخوخ *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) تحت ظروف المعمل

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الملخص

تم تقييم التأثيرات السامة والطاردة لبعض مصادر السيليكون المختلفة في شكل مسحوق وسوائل ضد ذبابة فاكهة الخوخ خلال فترة تعرض ٣ أيام تحت ظروف المعمل. في دراسة السمية ضد الحشرات الكامله وطور العذراء ، أظهرت النتائج تأثيرًا قويًا للسيليكون في شكل مسحوق مثل الدياتوم، الكاولين، أجليف اس اي ٣٠٠، والبنتونيت , وحققت نسبة الموت المصححة من ٤٠٪ إلى ١٠٠٪ على التوالي. أما في الشكل السائل، فقد أظهرت سيليكات البوتاسيوم تأثيرات سامة بنسب موت مصححة من ٥٥,٧٪ إلى ١٠٠٪. أظهر ملح البوتاسيوم و (الجير المغلي والكبريت) ومستحضر البالميتو تأثيرات سامة عالية. كما أظهرت النتائج أن البالميتو، الكاولين، البنتونيت، الجير المغلي والكبريت، وسيليكات البوتاسيوم الكاولينية أعلى فعالية في نسب طرد الحشرات مقارنة بالمواد الأخرى. أظهرمخلوط الجير المغلي والكبريت أعلى نسبة طرد ضد الحشرات الكامله ، حيث تراوحت النسبة من ٨٠٪ إلى ٣٣٪ بعد ١-٦ ساعات، وزادت إلى ٥٣,٠٪ - ١٠٠,٠٪ بعد ٢٤ ساعة. كانت سيليكات البوتاسيوم الكاولينية هي المادة الأكثر فعالية في الطرد ضد الحشرات الكامله ، و نسبة الطرد من ٣٥٪ إلى ٦٥٪ و٥٥٪ إلى ٩٥٪ بعد ١-٦ ساعات و٢٤ ساعة على التوالي في التركيزات المختلفة. كان مستحضر سى الغانم الأقل فعالية، حيث تراوحت نسبة الطرد من ٣٠٪ إلى ١٠٪ بعد ١-٦ ساعات ومن ٤٠٪ إلى ١٥٪ بعد ٢٤ ساعة. يمكن أن توفر مصادر السيليكون المدروسة بدائل مناسبة في برامج الإدارة المتكاملة للآفات.

الكلمات الدالة :. *Bactrocera* ,سميه, طارد, معادن, سيليكون