Arab Universities Journal of Agricultural Sciences
(2021) 29 (3) 901-912
Website: http://ajs.journals.ekb.eg

Greenhouse and Laboratory Evaluation of the Efficiency of Green Silicon Dioxide Nanoparticles Against *Tetranychus urticae* (Koch)

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https://doi.org/10.21608/ajs.2021.92246.1411

Received 24 August 2021 ; Accepted 23 October 2021

Keywords:

Tetranychus urticae, Biological control, Silicon dioxide nanoparticles, Acetylcholinesterase, Glutathione-S-transferase

Abstract: Nanotechnology takes a significant position in controlling pests. Silicon dioxide nanoparticles (SiO2-NPs) is considered one of the best alternatives to chemical pesticides for plant crop protection from harmful arthropods such as phytophagous mites, *Tetranychus urticae*. Therefore, this study aims to evaluate the effect of (SiO2-NPs) to control *T. urticae*. Under greenhouse conditions, the results revealed, in the larval stage, a high mortality percentage (99.05±0.83%) followed by eggs (98.74±1.22%). Besides, the nymph stage recorded high mortality (94.66±1.81%) at a high concentration of 1500 ppm. While the adult females of *T. urticae* recorded mortality of 91.92±1.02% after 72h. Eventually, the immature stages of *T. urticae* were susceptible to (SiO_2-NPs). Meanwhile, at laboratory evaluation on immature stages of *T. urticae* which resulted from live treated females during 96h showed a sharp decrease in average numbers of eggs through 96h, at 1000 and 1500 ppm. No numbers of the larval stage were recorded at 1500 ppm. No number of nymph stage were recorded at all concentrations and periods. Moreover, activity of AChE was significantly inhibited at 1500 ppm, while activity of glutathione-S-transferase was significantly increased after 72 h. Finally, (SiO_2-NPs) are effective against immature stages of *T. urticae* under greenhouse and laboratory conditions.

1 Introduction

Tetranychid mites are dangerous pests; they cause high economic losses in crops. The two-spotted spider mite, *Tetranychus urticae* (Koch), is one of the major pests attacking several crops such as field crops, vegetables, fruit trees, and ornamental plants (Huffaker et al 1970). Using chemical compounds to control pests creates many problems such as resistance to chemicals that are harmful to human health. The world is going to decrease chemical use and try to introduce nanotechnology as an alternate method. Nanotechnology occupied a significant position in controlling pests and its usage in technology and science to manufacture new materials (Albrecht et al 2006). It can produce new insecticide ingredients and innovative products, with notable weal to control agricultural pests (Ali et al 2011). New Silicon nanoparticles have shown promising possibilities in the scope of biotechnology. Also, silicon chemistry supplies the chance for a type of surface fictionalization with thiol, amine, and hydroxyl groups (Han et al 2009). Silicon is one of the most common materials on earth that has several pure

forms, i.e., quartz, clay rocks, and sand (Salleo et al 2003, Che et al 2003, Suzuki et al 2004). Sources of liquid silicon, such as potassium silicate, have been used to prevent feeding by phytophagous mites and other harmful pests (Hunt et al 2008, Reynolds et al 2009, Gatarayiha et al 2010, Korndörfer et al 2011). The existence of silicon in the plants can affect the plant's arthropod pests (Moraes et al 2004, Massey and Hartley 2009). Using silicon is a more suitable alternative to chemical pesticides for plant crop protection and control of harmful phytophagous arthropods. showed that silicon represses harmful insect pests such as green leafhoppers, stem borers, brown planthoppers, and phytophagous mites (Savant et al 1997, Ma and Takahashi 2002, Guével et al 2007, Keeping et al 2009). Nanoparticles might show several advantages other than their bulk material for their small size, and different shapes. Moreover, silicon is safe for human consumption by several regulatory agencies worldwide (O'Farrell et al 2006). Silicon nanoparticle insecticide causes injury to insects' cuticle water barrier by abrasion, and insect death occurs due to desiccation (Abd El-Wahab and El -Bendary 2016). This paper aims to evaluate the acaricidal activity of green silicon dioxide nanoparticles on the stages of *Tetranychus urticae*. Moreover, the effects of silicon dioxide nanoparticles in vitro on AChE and GST activities of adult females *T. uricae*.

2 Materials and Methods

2.1 Preparation of silicon dioxide nanoparticles

Green silicon dioxide nanoparticles (SiO_2-NPs) have been prepared using a rice husk, according to Pavitra et al (2018) with some modifications. The rice husk was refluxed for 3 hours with an acidic solution of 6 N HCl at 85 °C with a 1:10 w/v ratio. The acidified rice husk was then filtered and washed with distilled water six times, followed by drying at 70ºC overnight. Finally, to obtain silicon dioxide, nanoparticles were calcinated at a temperature of 500ºC for 2h.

2.1.1 Characterization of silicon dioxide nanoparticles

Characterization was carried out by Zetasizer and Scanning Electron Microscope. Scanning Electron Microscope (SEM) (JEOL- JSM-6360 L A, Nawah- Scientific center, Cairo, Egypt) instrument has been used to investigate the internal structure and surface morphology of green silicon dioxide nanoparticles. The particle size and zeta potential of green silicon dioxide nanoparticles in its colloidal solution were measured using a zetasizer after submission for 15 min of sonication (Zetasizer nano ZS, Nawah- Scientific center, Cairo, Egypt).

2.2 Bioassay of silicon nanoparticles

2.2.1 Greenhouse Experiments

This experiment was carried out in the greenhouse of the Horticultural Research Institute, Agricultural Research Center, Giza, Dokki, Egypt, on cucumber plants of the Hisham variety. Five groups of cucumber plants were selected to be sprayed with four concentrations of green silicon dioxide nanoparticles, which were 250, 500, 1000, and 1500 ppm, in addition to the control treatment with water only. Each group of plants consists of four replicates, with a total number of 20 plants. The experiment was in a randomized block design (RBD). Before starting the experiment, five leaves of cucumber plants were taken from each replicate randomly to determine the population density of mites. The spraying was done on the next day in the early morning for one time only, using a hand sprayer (Tigger spray pumps) with a capacity of 500 ml and the group of plants served as control **(Fig 1)**.

2.2.2 Mite parameters

Four leaves were collected randomly after 24, 48, and 72 h from each replicate/ concentration in addition to the control treatment. Leaves were placed inside plastic bags and transported to the laboratory for examination for three consecutive days, as mentioned previously. The numbers of eggs, larvae, nymphs, and females were counted one $inch^2$ in area using the dissecting microscope. The percentage mortality of mites was calculated according to the formula of Abbott (1925).

2.2.3 Laboratory Experiments

Four concentrations of silicon dioxide nanoparticles 250, 500, 1000 and 1500 ppm were evaluated under laboratory conditions against adult females of *T. urticae*. Twenty healthy adult females per four replicates were transferred to the treated leaf discs $4cm^2$ in area placed upside down on moist cotton wool in a Petri dish using a fine camel hair brush (5 individuals of female mite/leaf disc). Each concentration was sprayed using a hand spray atomizer at a 25–30 cm distance on the surface of leaf disc and the replicates which served as control were sprayed with water.

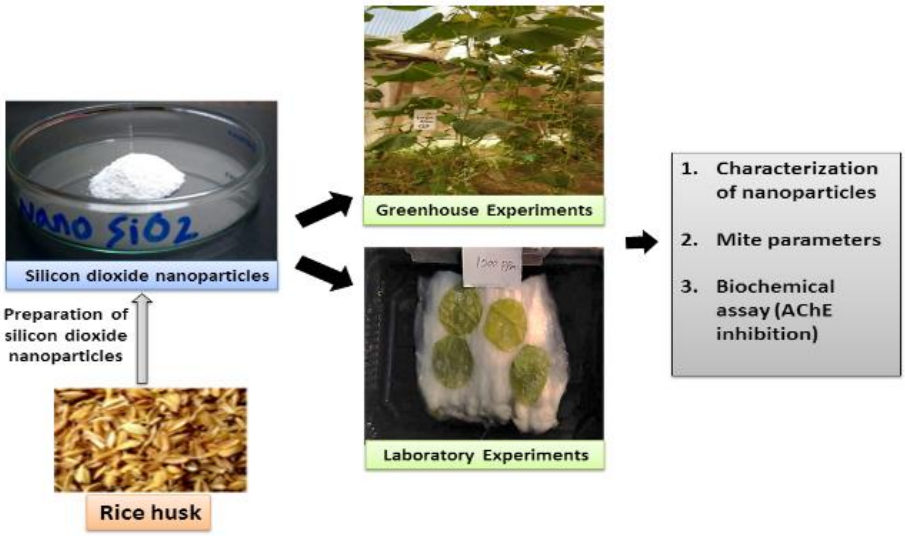

Fig 1. Graphic of greenhouse and laboratory experiments of silicon dioxide nanoparticles on *T. urticae*

Numbers of live and dead individuals were counted using the dissecting microscope after 24, 48, 72, and 96 h. Also, the average number of stages resulting from the live-treated females (eggs, larvae, and nymphs) at each concentration was calculated in **Fig 1**. All the experiments reported herein were carried out under the laboratory conditions of and RH.

2.3 Biochemical assay

Adult females of *T. urticae* (120 mg) were homogenized in 300 µl of Tris–HCl buffer (0.05 M, pH 7.5), then centrifuged for 5 min at 10,000× g and 4°C. The supernatant was used to determine the activity of (AChE) and (GST).

(AChE) inhibition was determined by the procedure of Ellman et al (1961). The mixture of reactions consisted of 50 µl of enzyme and 100 µl of 0.01 M 5.5'-dithiol-bis (2-nitrobenzoic) acid (DTNB) has been added to 2.8 ml of phosphate buffer (0.1 M, pH 7.8). Then, 20 µl of test solutions for silicon dioxide nanoparticles were transferred to this mixture and incubated at 37ºC for 15 min. The reaction was initiated with the addition of 30 µl of acetylthiocholine iodide, accompanied by incubation for 10 min at 37ºC. Absorbance was recorded using the Spectrophotometer at 412 nm (UV-Vis Spectrophotometer UV 9100B, Lab-Tech). The silicon dioxide nanoparticles were examined at four concentrations, 250, 500, 1000 and 1500 ppm. All test and control (without silica nanoparticles) runs were corrected by blanks for non-enzymic hydrolysis. Inhibition (%) of AChE activity was then calculated as follows: AChE inhibition (%) = $((O.D_B - O.D_T) / O.D_B)$ 100. Where $O.D_B$ is the optical density of the blank enzyme, and $O.D_T$ is the optical density of the treatment. The glutathione-s-transferase assay kit was measured according to the method described by Wilce and Parker (1994) using 1-chloro-2, 4 dinitrobenzene (CDNB), and reduced glutathione (GSH) as a substrate. The reaction mixture was prepared from 50 µl of CDNB (dissolved in ethanol 0.1 %), 50 µl of enzyme extract, and 50 µl of GSH 100 in Tris-HCl (0.05 M, pH 7.5). The absorbance change was continuously recorded at 340 nm for 5 min. Also, protein content was determined in enzyme extract according to Bradford (1976) using bovine serum albumin as a standard.

2.4Statistical analysis

Data of all results of the mortality percentage of mites were analyzed according to Steel and Torrie (1984). The means were compared by Duncan's Multiple Range Test (DMRT) at 5%, clarified by the LSD test Duncan (1955).

Values of chemical results presented are the means and standard deviations for three replicates**.** Statistical analysis was carried out by repeated measures Analysis of Variance (SAS system). Moreover, the recorded results were treated statistically using the one-way analysis of variance. The significance level was defined at $p \leq 0.05$ using Duncan's multiple range test (Snedecor and Cochran 1980).

3 Results and Discussion

3.1 Characterization of silicon dioxide nanoparticles

Scanning electron microscope images of silicon dioxide nanoparticles are shown in **Fig 2**, SEM analysis data showed that uniformly distributed silicon dioxide nanoparticles were in the agglomerated form. The zetasizer findings showed that the size of silica nanoparticles was about 35.23 nm. Zetasizer results are also shown in **Fig 3.** The negative zeta surface potential of silicon dioxide nanoparticles was reported, and the zeta potential value of nanoparticles of silicon dioxide was maintained at -25.6 mV.

3.2 Mortality percentage of *T. urticae* as affected by silicon dioxide nanoparticles under greenhouse conditions

Table 1 and Fig 4 represent the effect of different concentrations of silicon dioxide nanoparticles on the different stages of the two-spotted spider mite, *T. urticae*. There were highly significant differences among silicon dioxide nanoparticle concentrations that showed high mortality percentages during 72h of treatment at each time interval of all stages. Larval stage recorded a high mortality percentage after 24h of treatment at all concentrations, but it emerged clearly at 1500 ppm and was recorded at 45.84±1.06% compared to control treatment at 6.64±0.13%. This was followed by the egg stage, where a high mortality percentage was recorded at 44.02±0.42% and 34.92±0.16% at 1500 and 1000 ppm was recorded compared to other concentrations and the control treatment. The nymph and adult females were recorded 39.36±1.53 and 38.89±0.05% at 1500 ppm respectively, compared to the control treatment that recorded 4.44±0.02 and 2.94±0.21%, respectively. While the lowest mortality observed in adult females at 250 ppm was 18.01±0.11%.

Similarly, after 48h, the larval stage at 1500 ppm recorded high mortality percentage of 83.15 ± 0.03% then eggs, nymphs, and adult females 79.67±0.02, 78.77±3.63, and 68.87± 4.56% were recorded respectively, compared to the control. The mortality percentage recorded a high increase after 72h of all stages and at high concentrations and recorded significantly high differences. The larval stage recorded a mortality percentage of 99.05± 0.83% followed by eggs 98.74±1.22 and recorded at 1500 ppm compared to control. While of nymph stage at 1000 and 1500 ppm were recorded at 94.52±1.79 and 94.66±1.81% respectively. The adult females also recorded a high mortality of 91.92±1.02% at the high concentration compared to control. Finally, the immature stages of *T. urticae* were more susceptible to silicon dioxide nanoparticles than adult females.

3.3 Numbers of stages resulting from live treated females of *T. urticae* as affected by silicon dioxide nanoparticles under laboratory conditions

Laboratory evaluation of silicon dioxide nanoparticles on immature stages of *T. urticae* resulting from live-treated females through 96h is shown in **Table 2 and Fig 5.** It was noted that the average number of eggs decreased sharply by increasing the concentration and the time after treatment and the differences were highly significant at all concentrations. The lowest average number of eggs at 1500 ppm after 72, 48 and 24h were 0.25±0.20, 0.75±0.39 and 1.25±0.45 individuals respectively, while after 96h at the same concentration, no number of eggs were recorded compared to the control which recorded 80.25±1.64 individual. The numbers of the produced larvae were decreased by increasing the concentration and the time. No significant differences were recorded at 250 and 500 ppm between average numbers of the larval stage, and the lowest values were recorded after detected hours of treatments compared to control. While at 1000 ppm, only a few numbers of larvae were recorded (0.75 ±0.48 and 0.50±0.36) after 24 and 48h respectively. No larvae were recorded at 1000 ppm after 72 and 96h. Also, at 1500 ppm, no larvae were recorded after all detected hours. No nymphs were recorded at all concentrations compared to the control, and the life cycle of *T. urticae* was not completed.

3.4 Inhibitory effect of silicon nanoparticles on the activity of acetylcholinesterase (AChE)

The in vitro inhibitory action of different silica nanoparticles' concentrations on the AChE activity of adult females *T. urticae* is shown in **Table 3** at all concentrations. The activity of AChE has been significantly inhibited, and the maximum inhibition was caused by silicon dioxide nanoparticles at 1500 ppm (97.5%), followed by 1000 ppm (78.6 %) inhibitory activity. Silicon dioxide nanoparticles showed moderate inhibition activity at 500 ppm (56.6 %), while silicon dioxide nanoparticles were not capable of inhibiting AChE at 250 ppm; this causes far less inhibition than 50 percent. The inhibition of AChE activity could be the reason for the highest mortality of adult females at 1000 and 1500 ppm.

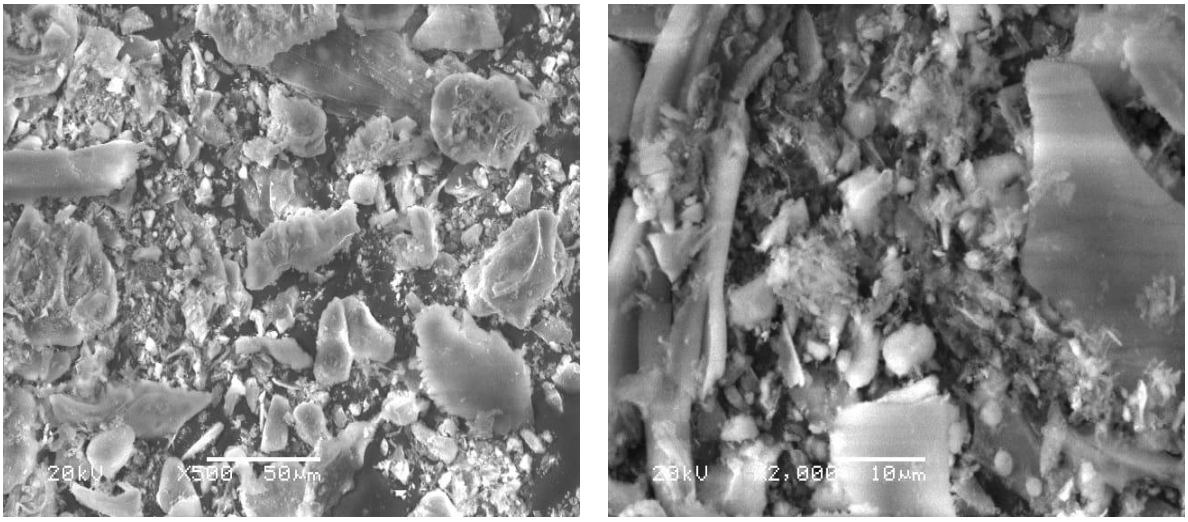

Fig 2. SEM images of the silicon dioxide nanoparticles at magnification × 500 and 2000

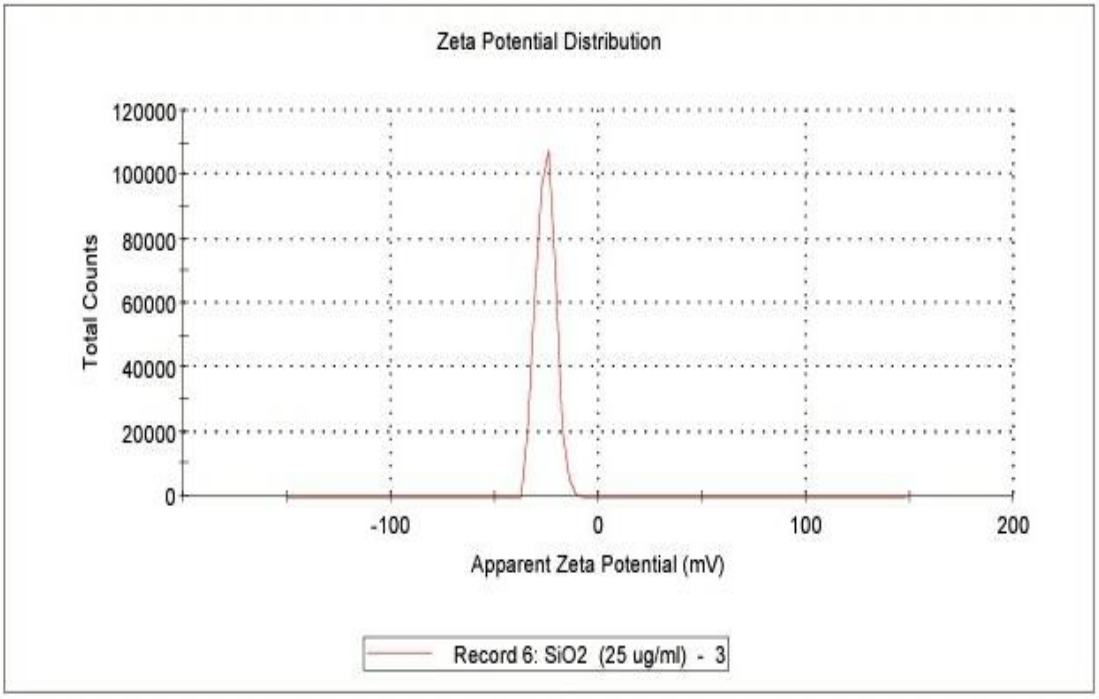

Fig 3. Zeta potential of green silicon dioxide nanoparticles.

Table 1. Mortality percentage of different stages *T. urticae* as affected by silicon dioxide nanoparticles under greenhouse conditions

Time after treatment (h.)	Conc. (ppm)	Mortality % of *T. urticae* stages			
		Eggs	Larvae	Nymphs	Adult Females
24	250	20.12±0.06 ^{c}	28.25±0.02 ^{d}	25.01 ±0.87 ^{d}	18.01± 0.11^{d}
	500	28.09± 0.04 ^{b}	31.91±1.24 ^{c}	31.60± 1.80 ^{c}	24.83± 0.11^{c}
	1000	34.92±0.16 ^{b}	38.87 ±0.25 ^{b}	37.09 ±1.08 ^{b}	32.50±0.04 ^{b}
	1500	44.02±0.42 ^{a}	45.84±1.06 ^{a}	39.36±1.53 ^{a}	38.89 ±0.05 ^{a}
	Control	1.17±0.03 ^{d}	6.64 ±0.13 ^{e}	4.44± 0.02 ^{e}	2.94 ±0.21^{e}
	F. Value	0.02**	2.03**	12.95**	1.93**
	P. Value	0.88	0.18	0.04	0.19
	L.S.D	4.07	1.79	2.41	1.39
48	250	42.09± 0.15 ^{d}	50.90± 0.03 ^{d}	45.42± 0.08 ^{d}	34.70± 0.29 ^{d}
	500	56.17 ±0.05 ^{c}	63.40 ±0.12 ^{c}	60.26± 0.04 ^{c}	53.82± 0.79 ^{c}
	1000	72.42± 0.05 ^{b}	76.67± 1.45 ^{b}	70.77± 0.02 ^{b}	61.57 ± 0.64 ^{b}
	1500	79.67±0.02 ^{a}	83.15 ± 0.03 ^{a}	78.77 ±3.63 ^{a}	68.87 ± 4.56 ^{a}
	Control	0.58 ±0.07 ^{e}	1.48 ±0.07 ^{e}	1.02 ± 0.02 ^{e}	2.21 ±0.31 ^{e}
	F. Value	0.29**	0.68**	0.45**	1.38**
	P. Value	0.59	0.43	0.52	0.26
	L.S.D	3.90	3.53	3.44	3.92
72	250	61.65± 0.65 ^{d}	78.92±1.65 ^{d}	72.75± 0.21 ^{d}	52.48 ±1.35 ^{d}
	500	77.21±1.26 ^{c}	90.10 ±1.22 ^{c}	89.69± 2.38 ^{c}	68.75 ±4.55 ^{c}
	1000	90.91±0.10 ^{b}	95.29 ±1.76 ^{b}	94.52 ±1.79 ^{b}	88.32 ±2.47 ^{b}
	1500	98.74 ±1.22 ^{a}	99.05±0.83 ^{a}	94.66 ±1.81 ^{a}	91.92 ±1.02 ^{a}
	Control	0.29 ±0.03 ^{e}	0.37 ±0.09 ^{e}	0.34± 0.08 ^{e}	0.00 ±0.00 ^{e}
	F. Value	0.48**	1.19**	0.36**	1.05**
	P. Value	0.50	0.29	0.56	0.32
	L.S. D	0.02	1.24	0.04	0.01

Means with the same letter within each column are not significantly ($P \leq 0.05$; using Duncan's Multiple Ranges test at 5% clarifying by LSD test).

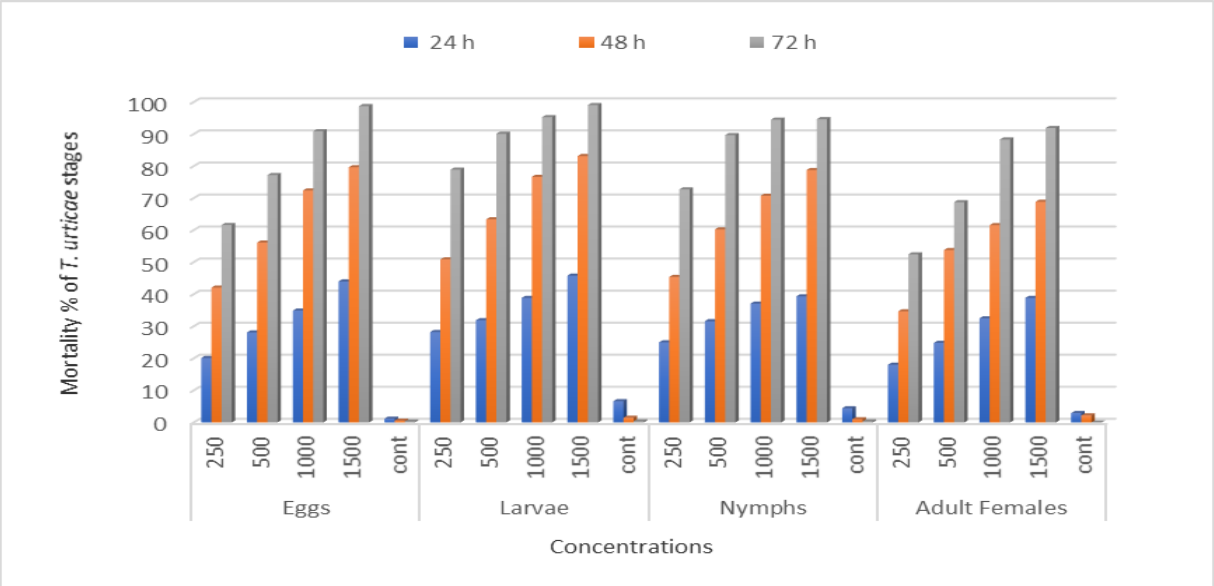

Fig 4. Mortality percentage of different stages *T. urticae* as affected by silicon dioxide nanoparticles under greenhouse conditions

Table 2. Average numbers of stages resulting from live treated females of *T. urticae* as affected by silicon dioxide nanoparticles under laboratory conditions

Stages	Conc. (ppm)	Average numbers of *T. urticae* stages after detected hours (h.)			
		24	48	72	96
No. of Eggs	250	38.25±3.27 [b]	29.50±2.44 [b]	24.75±0.68 [b]	9.00± 0.73 [b]
	500	25.25±2.04 [c]	22.00 ±0.91[c]	16.50±1.43 [c]	7.50 ±0.58 [c]
	1000	8.50±0.96 [d]	5.00 ±0.74 [d]	3.50 ±0.99 [d]	1.50 ±0.24 [d]
	1500	1.25 ±0.45 [e]	0.75 ±0.39 [e]	0.25 ±0.20 [e]	0.00±0.00 [e]
	Control	46.50 ±0.98 [a]	58.25 ±2.03 [a]	66.5± 1.20 [a]	80.25 ±1.64 [a]
	F. Value	0.01**	1.91**	0.04**	4.82**
	P. Value	0.92	0.19	0.85	0.05
	L.S. D	0.07	3.69	2.04	0.83
No. of Larvae	250	3.25 ±0.35 [b]	2.00 ±0.55 [b]	1.75± 0.37 [b]	1.25± 0.39 [b]
	500	3.00 ±0.59 [c]	1.75± 0.34 [c]	1.00±0.55 [c]	0.75±0.40 [c]
	1000	0.75± 0.48 [d]	0.50±0.36 [d]	0.00± 0.00 [d]	0.00±0.00 [d]
	1500	0.00 ±0.00 [e]	0.00 ±0.00 [e]	0.00 ±0.00 [d]	0.00±0.00 [d]
	Control	36.50±2.29 [a]	48.25±2.79 [a]	56.50±1.23 [a]	67.75±2.24 [a]
	F. Value	0.21**	0.77**	4.25**	0.10**
	P. Value	0.65	0.39	0.06	0.76
	L.S. D	0.01	0.33	0.01	0.01
No. of Nymphs	250	0	0	0	0
	500	0	0	0	0
	1000	0	0	0	0
	1500	0	0	0	0
	Control	25.75± 1.44	34.00±1.55	44.25±0.86	56.75±2.69

Means with the same letter within each column are not significantly ($P \leq 0.05$; using Duncan's Multiple Ranges test at 5% clarifying by LSD test).

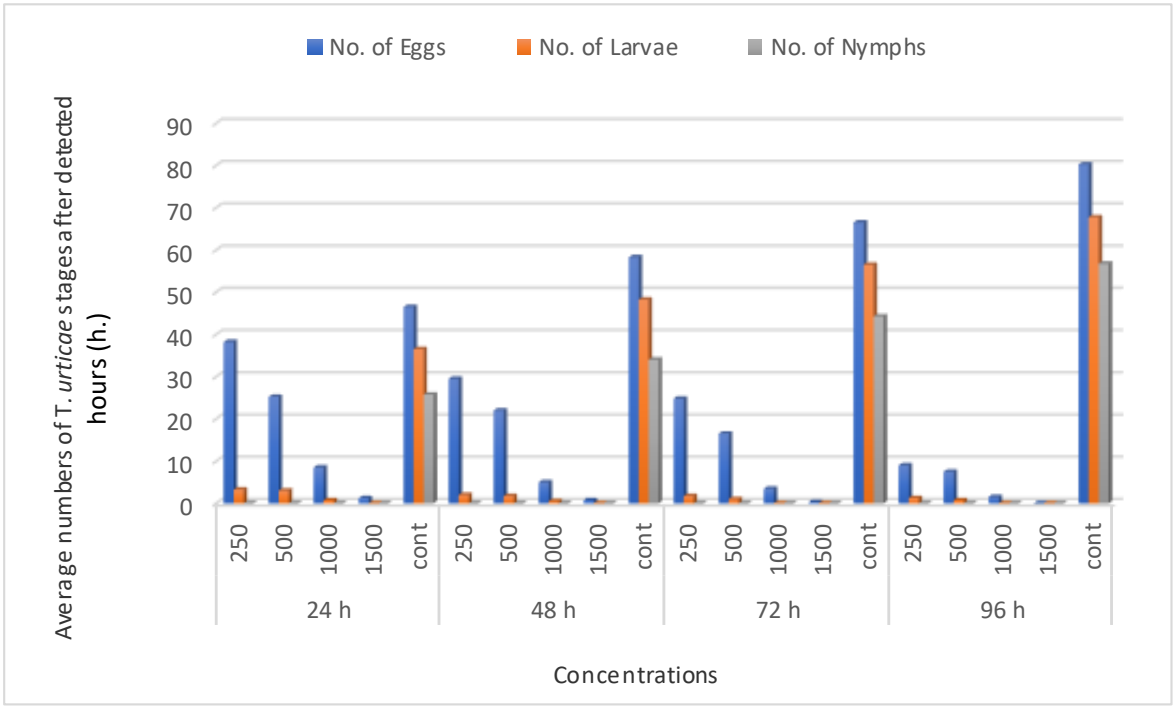

Fig 5. Average numbers of stages resulting from live treated females of *T. urticae* as affected by silicon dioxide nanoparticles under laboratory conditions

Table 3. Inhibition of acetylcholinesterase activity of adult females *T. urticae* by silicon dioxide nanoparticles

Conc. (ppm)	% inhibition of acetylcholinesterase
250	$39.9^{d} \pm 0.26$
500	$56.6^{c} \pm 0.82$
1000	$78.6^{b} \pm 0.38$
1500	$97.5^{a} \pm 0.46$

The % inhibition of acetylcholinesterase is presented as the means of three replicates ± SD

The results in **Table 4** represent the activity of (GST) of *T. urticae* treated with different concentrations of SiO_2 nanoparticles after 72 h. The results indicated that treatment of adult females, *T. urticae* with silica nanoparticles at concentrations of 1000, and 1500 ppm leads to a significant increase in Glutathione-S-transferase activity compared to control while treatment of *T. urticae* with silica nanoparticles with concentrations 250 and 500 ppm showed significantly similar GST activity 756.91 and 762.33 µmole/ min/mg, respectively.

Table 4. Effect of green silicon nanoparticles on Glutathione-S-transferase activity of adult females *T. urticae* after 72 h

Conc. (ppm)	Glutathione -S-transferase activity µmole/ min/mg protein
Control	$623.00^{d} \pm 1.22$
250	$756.91^{c} \pm 1.06$
500	$762.33^{c} \pm 0.82$
1000	$899.52^{b} \pm 1.38$
1500	$973.05^{a} \pm 1.46$

Glutathione-S-transferase activity is presented as the means of three replicates ± SD.

The results are in harmony with that of Manzoor and Zaki (2020) who demonstrated that silicon dioxide nanoparticles caused a high reduction of nematode multiplication *Meloidogyne incognita* in root galling of beet (*Beta vulgaris* L) under greenhouse conditions. Shaker et al (2020) proved that SiO2 nanoparticles caused the highest effect against *Thrips tabaci* on cotton seedlings at high concentrations under field conditions. Ali et al (2018) proved that silicon dioxide nanoparticles caused a high mortality percentage against larvae of *Plutella xylostella*, after 72 h of treatment by using the dust spray method under laboratory conditions. Thabet et al (2021) proved that silica (SiO2) nanoparticles have the scope to control insect pests such as *Spodoptera littoralis*, *Aphis craccivora* and *Liriomyza trifolii* where they reduced the population densities when using the high concentrations under field conditions.

Azlina et al (2016) and Wardiyati et al (2017) indicated that the synthesis of green silicon dioxide nanoparticles (SiO2) was characterized by different characterization techniques and possessed the characteristics of being nanoparticle. Also, a Scanning Electron Microscope (SEM) was used to study the morphology of silicon dioxide nanoparticles that consist of fine particles, which resulted in irregular arrangements. Ali et al (2018) showed the size and zeta of silicon dioxide nanoparticles prepared in this study were checked using zetasizer which showed nano silicon has a negative surface zeta potential with a diameter of 35.23 nm.

Also, Arkadiusz (2018) proved that silicon depositions might supply a mechanical barrier against harmful pests and crop diseases' physiological resistance. Silicon plays an essential role in physiological resistance through chemical production, tannic and phenolic groups, so silicon usage is now available (IPM program). Also, Basagli et al (2003), Moraes et al (2004) and Kordan et al (2005) showed that the application of silicon to susceptible wheat reduced pest infestation and increased crop resistance in the field**.** Salim and Saxena (1992) revealed that the high levels of silicon decreased the numbers of hopper nymphs and decreased adult female fecundity and longevity. Nikpay and Soleyman (2014) showed that there was a significant decrease in mites' population density in all the silicon-treated plots compared to the control. According to the importance of applying IPM programs in fields that combine acaricides with other reduce-risk strategies.

Moreover, Dorri et al (2018) revealed that the use of CuO nano-capsule significantly reduced the population of the two-spotted spider mite on the red bean plant. Abdel-Halim and Kalmosh (2019) showed that in a laboratory test, nano-abamectin was more toxic to the adult female of *T. urticae* (Koch) with a value of 30 than Vertimec 1.8% EC. Also, nano-abamectin reduced the mite fecundity at higher levels than those of Vertimec. At the field, nano-abamectin at the rate of 60 ml/ha recorded highly toxic effects (89.98 % mortality) after 72 h of spraying on soybean plants. So, the

bioactivity of nano-acaricide was much higher than traditional acaricides on *T. urticae*. Alakhdar (2020) showed that a field experiment produced a 94.35% mortality percentage of *T. urticae* after three days of treatment by using chitosan nanoparticles to be acaricides. Alireza et al (2013) conducted the bioassay by leaf dipping and spraying techniques which showed significant differences in the mortality effect of silver nanoparticles on adult mites by using leaf dipping techniques at concentrations 2.5, 5, 10, 50, 100, 200, 500, 1000, 2000, and 3000 ppm, which is based on the increase in concentrations at different periods.

Abd El-Rahman (2017) showed cyhalothrin nano-partial was the most effective compound against eggs' hatchability and adults of *T. urticae*. Under field conditions, all nanoparticle compounds achieved an excellent effect on *T. urticae* in cotton plants. Rai et al (2014) proved that nanoparticles that penetrate through the exoskeleton in insects then bind to sulfur from proteins or phosphorus from DNA, leading to the rapid damage of organelles and enzymes. Due to the decrease in membrane permeability and disturbance in proton motive force, cellular function damage occurs and the cell dies. Jiang et al (2015) and Benelli (2016) concluded that several nanoparticles can pass the blood-brain barrier and arrive to the central nervous system. Nanoparticles may bind to acetylcholinesterase (AChE) and affect its activity as an essential enzyme in the nervous system. This enzyme is responsible for the correct transmission of nerve impulses by hydrolyzing the neurotransmitter acetylcholine into choline and acetic acid in cholinergic synapses. Rouhani et al (2012) showed that, silver and zinc nanoparticles played an important role as a pesticide; they caused high mortality against *Aphis nerii* and can be used as a beneficial agent in pest management control programs.

Benelli (2018) and Gui et al (2009) reported that glutathione-S-transferase in insects represents a very important enzyme that carries out a detoxification mechanism due to its involvement in tolerance of acaricides and protecting tissues from oxidative damage and stress. Also, the glutathione-S-transferase enzyme plays a vital role in developing silicon dioxide nanoparticles and showing more potency against family Tetranychidae (Gui et al 2009, Ugurlu et al 2007). Also, Gholamreza et al (2021) toxicity effects of copper oxides (nano-CuO), nano magnesium oxide (nano-MgO), and nano zinc oxide (nano-ZnO) were highly effective against Bulb mite *Rhizoglyphus robini*. Moreover, Abdelslam et al (2021) reported that, in future generations, chitosan nanoparticles are the most antimicrobial activity in the environment.

4 Conclusion

Silicon dioxide nanoparticles are more effective on immature stages of *T. urticae* and susceptible, followed by adult females at high concentrations and at different time intervals under greenhouse and laboratory conditions. Moreover, the results showed that the activity of AChE has been significantly inhibited at 1500 ppm followed by 1000 ppm. Also, the activity of Glutathione-S-transferase significantly increased after 72h compared to the control. This investigation recommends applying silicon dioxide nanoparticles at 1000 and 1500 ppm concentrations for the suppression of phytophagous mites.

Abbreviations

(AChE**):** Acetylcholinesterase
(GST): Glutathione-S-transferase
(SEM): Scanning Electron Microscope

Acknowledgments

This work was done in the acarology and biochemistry Labs, at the Faculty of Agriculture, Ain Shams University, Cairo, Egypt. With no funding.

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