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Silica Nanoparticles Boosted Abamectin's Acaricidal Bioactivity Against *Tetranychus urticae* Koch's Two Spotted Spider Mite Developmental Stages

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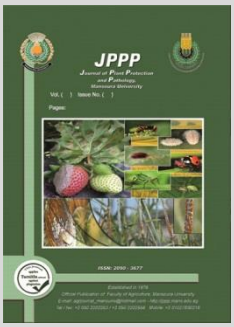

ABSTRACT

Under laboratory conditions, the sub-lethal effects of four agents [silica bulk, silica nanoparticles (NPs), two synthesis agents (silica bulk-abamectin, silica NPs-abamectin)] were compared to one synthetic acaricide (abamectin) against *Tetranychus urticae* immature stages. Sublethal concentrations (LC_{25}) of the tested agents against adult females of *T. urticae* were determined using standard bioassay procedures. The effects of sublethal concentrations of the investigated compounds on egg deposition and egg hatchability were measured over five days at 22 and 28 degrees Celsius, respectively. The effects of the investigated substances on the duration (in hours) of *T.urticae* developmental phases were evaluated at two different temperatures 22 and 28 ºC. The results showed that silica nanoparticles (NPs) coated with abamectin had a significant influence on egg deposited decrease by *T. urticae* adult females. By the way, silica NPs-abamectin was the most effective therapy for egg deposition and hatchability over five days at 22 and 28 ºC respectively, followed by abamectin. Furthermore, silica NPs-abamectin was found to be very beneficial in prolonging the length (in hours) of *T.urticae* developmental stages at different temperatures. This research reveals that silica bulk and silica nanoparticles (NP) might be employed as replacements for conventional acaricides and are compatible with IPM approaches. They could be useful in the future for pest management.

Keywords: *Tetranychus urticae*; immature stages; silica nanoparticles; abamectin.

INTRODUCTION

Tetranychus urticae Koch is a very economically important pest that can be found in a variety of outdoor and indoor environments around the world (FAO, IFAD, and WFP, 2018). The use of conventional acaricides is largely responsible for its control. Other significant concerns in *T. urticae* have been well documented to acquire tolerance and resistance to acaricides with distinct modes of action due to its short life cycle, prolific progeny, and rapid reproduction (Gent, 2009).

Many incidences of resistance to acaricides have been reported, resulting in a failure to manage mites populations efficiently (Feyereisen, 2012; Zhu *et al*., 2014). The two-spotted spider mite is commonly controlled with acaricides such as abamectin. However, abamectin, which has potent biological activity and a translaminar impact against *T. urticae*, is one of the most often used acaricides to control spider mites (CHEBI, 2020). As a result of the high reproductive potential, haplodiploid sexual reproduction, and short life cycle of *T. urticae*, repeated broad use of abamectin against its populations has resulted in control failures in many locations, facilitating the rapid development of resistance (Piraneo, 2013; Zayed, 2020). Indicating that a resistance-control approach based on a different method of acaricidal activity should be devised.

For the first time, nanoparticles (NPs) are being employed as insecticides. As a result, it is necessary to identify potential risk management concerns and to investigate the specific challenges of applying nanotechnology in pest control (Rouhanil *et al.*, 2008; Stone *et al*., 2010; Debnath, 2012; Song *et al*.,2012; AL Akhdar and El-Samahy, 2016; AbdelHalim, 2019; Emam *et al*., 2021). Nanoparticles contribute to the creation of new pesticides, insecticides, and repellants (Owolade *et al*., 2008). According to academics, nanotechnology will also change agriculture, particularly pest management, in the near future (Bhattacharyya *et al*., 2010). These nanoparticles' structural and functional properties include biocompatibility, biodegradability, low toxicity, and good miscibility with other polymers. They also have a highly chemically reactive structure together with biological activity (Rabea *et al*., 2003; Gerasimenko *et al*., 2004; Badawy 2008 and 2010).

Furthermore, semiconductor NPs offer a viable solution for removing pesticide residues via photocatalytic activity (Baruah and Dutta, 2009), as well as encouraging us to develop new green nanotechnology to control insect pests using a synergistic approach and subsequent degradation via photocatalytic activity, making them environmentally friendly (Jameel *et al*, 2020; Hussien *et al*., 2021). Furthermore, using pesticides sparingly can help to delay the development of insecticide resistance (Ojha *et al.*, 2018). Surprisingly, to our knowledge, only a few research publications have been published that examine the combined effects of NPs and organic pesticides in controlling plant damage caused by these insect pests (Malaikozhundan *et al.*, 2018; Vindarajan *et al.*, 2016; Pestovsky and Martnez-Antonio, 2017).

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T.urticae's life activities are strongly linked to environmental conditions, and temperature plays an important role in arthropod development and reproduction (Gotoh *et al*., 2010). *T. urticae* has a typical warm-weather spider mite life cycle. At 27.5 - 32.5ºC, the entire life cycle takes around 7-8 days, and all life phases are present throughout the year, depending on environmental circumstances (James and Price, 2002).

The purpose of this study was to compare the sub-lethal effects of the tested agents (silica bulk, silica nanoparticles (NPS), and two synthesis agents (silica bulk-abamectin, silica NPs-abamectin) to one synthetic acaricide (abamectin). The improved effects of silica bulk-abamectin and silica NPs-abamectin against *T.urticae* immature stages were determined. We investigated the entomotoxicity of silica nanoparticles against *T.urticae* based on these cues.

MATERIALS AND METHODS

Tested mites

T.urticae reared in the Dittrich method (1962). To boost plant growth, *T. urticae* colonies were taken from castor bean plants in the Damietta Governorate and cultivated in the laboratory at 25± 2°C under a 16:8 (light: dark) photoperiod and 70±5 R.H. Mites were transferred from one plant to another using a No. 0 brush.

Tested agents

Egypt Nanotech Company limited, El-Wahaat Road, Cairo, Egypt, provided Silica bulk (S bulk) with a purity of 99.99 percent, a density of 2.65, and a molecular weight (60.08 g), as well as Silica nanoparticles (SNPs) with a purity of 99.99 percent and an application size (APS) of 50 nm. Abamectin (Ab) was produced by the EL-HELB Company in New Damietta, Egypt, and was utilized in technical grade.

Synthesis of silica nanoparticles

With certain modifications, the silica nanoparticles were produced utilising the protocols of Mathew and Narayanankutty, (2010) and Aslani *et al.*, (2003). The nano-silica was created by the acid hydrolysis of sodium silicate using 15% dilute hydrochloric acid. A sodium silicate solution was created using a 1% polyvinyl alcohol solution. Then, at a temperature of 60ºC, 0.5 NHCl was added slowly while stirring. The solution's pH was regulated between 1 and 2. The solution was stirred at 60°C for 30 minutes to perform the acid hydrolysis of sodium silicate. The sol-gel mixture was then vigorously washed to remove all of the sodium chlorides that had formed. It was muted at 600 degrees Celsius after drying at 50 degrees Celsius.

Synthesis of abamectin silica nanoparticles (Ab-SIO2 NPS)

Abamectin was added to SIO_2 NP (5:1) water suspension under mild magnetic stirring at room temperature (27 °C) for 30 minutes, followed by aging at 27 °C for 1 hour, according to Shoeb *et al.* 2018. The reaction mixture was heated to 50 °C after aging and kept at that temperature for 60 minutes. A white color precipitate is generated, which is rinsed twice with double distilled water before dried in a hot air oven at 50 °C for 2 hours.

Determination of LC_{25} of tested agents to adult females of two-spotted spider mite *T.urticae*

To determine if the investigated substances had a sublethal effect on adult female *T.urticae*, all compounds were examined using Finney's leaf disc dip technique (1971). The active component was diluted to specific quantities (ppm) in the manufactured chemicals. All dilutions were done with distilled water. Four castor bean leaf discs were immersed for 5 seconds in each concentration and then dried. After that, 10 adult female mites were placed on each disc. The discs were placed on wet filter paper, which was placed in Petri plates with a moist cotton wool pad and kept in the same conditions as the breeding room. Counts of deaths were taken 24 hours following therapy. Abbott's formula was used to correct for control mortality (1925).

The sublethal effects of tested agents against *T. urticae* eggs deposition and hatchability at 22 and 28 ºC

The technique recommended by Keratum *et al.* (1994) was utilized to determine the sub-lethal effect of each tested treatment at the LC_{25} level on adult females of *T. urticae*. After dipping each disc in the LC_{25} concentration of each investigated chemical, ten adult female *T. urticae* of known age were inserted on each disc. The sublethal concentrations effect of the tested agents (LC_{25}) on eggs laid by adult females was investigated. For five days, five mature female mites were allowed to oviposit on various compounds-treated discs. The deposited eggs were counted every day. Each treatment was carried out four times in total. Five days after egg deposition, the number of hatching eggs was also counted. The evaluation took place between the ages of 22 and 28 ºC with 16 hours of photoperiod. Each treatment was replicated four times.

Effect of the tested treatments on developmental rate of *T. urticae* at 22 and 28º

The temperature range utilized was deemed to be the optimum for the successful life cycle development of *T. urticae* immature stages, which were measured at 22 and 28 ºC, according to earlier research. Experiments were carried out using the Keratum *et al.* (1994) approach. Five young females were collected from the colony and placed on the leaves at each temperature examined. The eggs were transferred to the experimental leaves, with 10 eggs per leaf. Every three days, the leaves were replaced. Daily observations were made, and the growth of immature stages on each leaf was tracked.

Statistical analysis

To correct percent mortality, according to natural mortality, Abbott's formula (1925) was employed.

$$\text{Mortality (\%)} = \frac{\text{Mortality \% of treatment - mortality \% of control}}{\text{Mortality \% of control}} \times 100$$

Sun (1950) was used to calculate the LC25 toxicity index for the investigated compounds, with the following modifications:

$$\text{Toxicity index} = \frac{LC_{25} \text{ of the most effective compound}}{LC_{25} \text{ of the tested compound}} \times 100$$

According to Mohamed (2006), the percentage reduction in egg-laying for each treatment was estimated as follows:

$$\text{\% Reduction} = \frac{\text{No. of treatment} - \text{No. of control}}{\text{No. of control}} \times 100$$

Costat Statistical Software (2006) was used to evaluate the mortality data, which was followed by a one-way analysis of variance (ANOVA) and Duncan's multiple range tests (1955). The results were reported as means (±SE) of untransformed data, and *P*0.05 was used to determine whether they were substantially different. The mean of each treatment

was separated using Fisher's least significant difference (LSD) test. The Probit analysis software was used to estimate LC_{25} values and associated fiducial limits using Probit analysis.

RESULTS AND DISCUSSION

Results

Table 1 shows that Ab- SNPs were the most potent agents to adult females of *T. urticae*, followed by SNPs, Ab-S bulk, Ab., and S bulk, with LC_{25} values of 0.158, 0.542, 1.001, 2.239, and 3.967 ppm, respectively. In addition, Fig. (1) depicted the toxicity index of the tested treatments, with Ab- SNPs having the highest toxic index factor with a value of 100 and S bulk having the lowest toxic index factor with a value of 3.98 in comparison to the most effective treatment.

Table 1. Determination of LC_{25} of the tested agents against adult females of *T. urticae*

Treatment	Heterogeneity		Regression equation	LC_{25} (ppm)	Fiducial limits		Slope	Toxicity index
	X^2	*df*			Lower	Upper		
S bulk	1.398	8.00	0.960±0.836	3.967	2.071	5.259	3.205	3.98
S NPs	0.765	8.00	0.977±+0.705	0.542	0.259	0.738	2.626	29.15
Ab- S bulk	0.732	8.00	0.976±0.805	1.001	0.474	1.370	2.831	15.78
Ab- SNPs	2.114	8.00	0.937±0.644	0.158	0.031	0.593	2.390	100.00
Ab.	2.915	8.00	0.937±0.749	2.239	1.211	2.961	3.009	7.056

Silicon dioxide bulk (S bulk); Silicon dioxide nanoparticles (SNPs); Abamectin silicon dioxide (Ab-S bulk); Abamectin Silicon dioxide nanoparticles (Ab-SNPs); Abamectin (Ab).

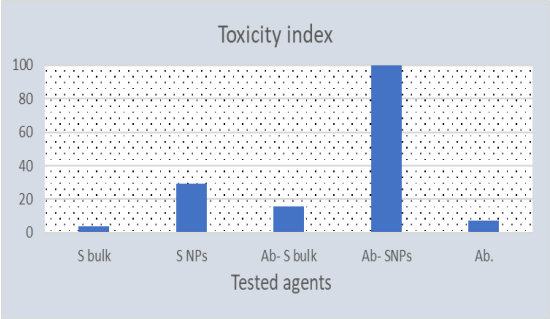

Fig. 1. Toxicity index of LC_{25} values of tested agents against adult females of *T. urticae*

Tables 2, 3, and Figs. 2, 3 showed that abamectin silica NPs, then abamectin-silica bulk, induced the greatest reduction in egg deposition, followed by silica NPs, which were equal to abamectin treatment. Silica bulk caused a slight reduction (percent reduction) in adult female mite egg deposition. When compared to controls, SNPs had a significant effect on the number of eggs deposited/5 adults over the course of five days.

Table 2. Effect of sublethal agents' concentrations on egg deposition of spider mite *T. urticae* at 22 ºC

Treatment	No. of egg deposited/5 adults					Grand mean
	1st day	2nd day	3rd day	4th day	5th day	
S bulk	12.33^{b}±0.127	13.17^{b}±0.213	14.38^{b}±0.082	15.51^{b}±0.187	17.59^{b}±0.280	14.59^{b}±0907
S NPS	8.33^{c}±0.161	9.16^{c}±0.014	10.41^{c}±0.133	12.57^{c}±0.208	14.47^{d} ±0.302	10.99^{c}±0.134
Ab- S bulk	6.43^{e}±0.228	8.27^{e}±0.094	9.52^{d}±0.262	11.46^{d}±0.215	12.32^{e}±0.288	9.60^{d}±0.121
Ab- SNPs	4.40^{f}±0.223	5.35^{f}±0.121	6.65^{e}±0.078	8.41^{e}±0.205	11.42^{f}±0.144	7.25^{e}±0.036
Ab	7.28^{d}±0.089	8.41^{d}±0.061	10.60^{c}±0.199	12.30^{c}±0.083	15.63^{c} ±0.153	10.84^{c}±0.046
Control	20.64^{a}±0.127	22.34^{a}±0.268	25.68^{a}±0.281	30.37^{a}±0.112	31.80^{a}±0.397	26.16^{a}±0.123
L.S.D. (0.05)	0.528	0.470	0.637	0.589	0.891	0.313

Table 3. Effect of sublethal agent's concentrations on egg deposition of spider mite *T. urticae* at 28 ºC

Treatment	No. of egg deposited/5 adults					Grand mean
	1st day	2nd day	3rd day	4th day	5th day	
S bulk	15.41^{b}±0.141	16.33^{b}±0.037	17.26^{b}±0.100	18.51^{b}±0.187	19.70^{c}±0.981	17.44^{b}±0.011
S NPs	12.14^{c}±0.096	13.49^{c}±0.332	14.16^{c}±0.294	15.57^{d}±0.208	16.91^{e}±0.338	14.45^{d}±0.363
Ab- S bulk	9.19^{e}±0.112	10.48^{e}±0.132	12.32^{e}±0.031	14.27^{e}±0.103	18.15^{d}±0.368	12.89^{e}±0.138
Ab- SNPs	6.36^{f}±0.126	7.41^{f}±0.256	8.33^{f}±0.147	10.41^{f}±0.205	13.34^{f}±0.185	9.17^{f}±0.088
Ab.	10.25^{d}±0.102	12.19^{d}±0.089	13.32^{d}±0.242	17.27^{c}±0.192	22.56^{b}±0.278	15.12^{c}±0.095
Control	30.54^{a}±0.176	32.57^{a}±0.206	35.88^{a}±0.510	40.29^{a}±0.088	51.49^{a}±0.307	38.16^{a}±0.050
L.S.D. (0.05)	0.437	0.522	0.910	0.589	0.797	0.548

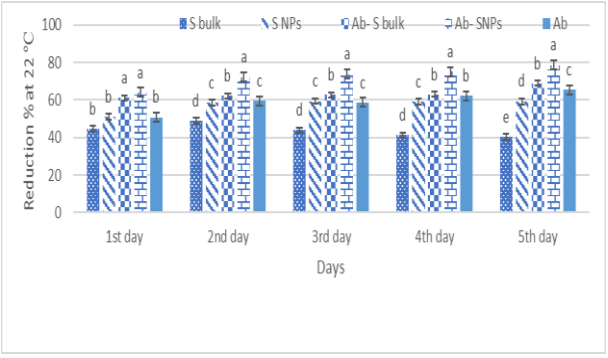

Fig. 2. Reduction percentage in the egg-laying capacity of *T. urticae* / 5 females due to the tested agents at 22 ºC.

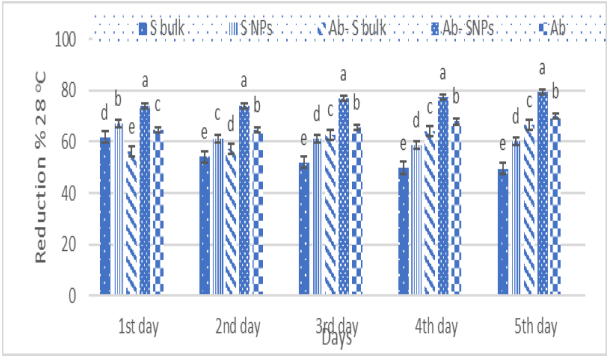

Fig. 3. Reduction percentage in the egg-laying capacity of *T. urticae* / 5 females due to the tested agents at 28 ºC.

In terms of egg hatchability, the data in Tables 4 and 5 indicated that all treatments had an influence on eggs hatched after further five days/5 adults, resulting in a reduction in egg hatchability. The most effective treatment was silica nanoparticles coated with abamectin, which reduced *T.urticae* egg hatchability, followed by silica bulk loaded on abamectin. Silica nanoparticles, on the other hand, have a significant impact on egg hatchability. At 22 and 28 ºC, silica bulk has a minor effect on egg hatchability. All of the treatments significantly reduced the egg's hatchability over the course of five days.

Table (6) refers to the duration of the overall time of the life cycle that was lengthened in the presence of the tested treatments at 22 and 28ºC. In the tested mite exposed to the studied treatments, the mean larval and protonymphal durations were significantly longer. At 22 ºC, the effect of treatments at the overall time of the life cycle is greater than 28 ºC. The use of tested therapies appears to have had a significant impact on mortality and the growth of the surviving mites. The sub-lethal effect of testing treatments at 28ºC lengthened the developmental period needed to attain adulthood. The mortality rate was lower at these temperatures than at 22°C, but overall, the mortality rate was higher. When compared to control, was higher for mites exposed to the tested treatments. The tested therapies resulted in greater mortality and delayed development, the latter of which could be related to a toxic side effect. The presence of tested treatments on the leaf surface may function as an irritant or repellent, or make the plant substrate less attractive for mite growth, potentially affecting the time it takes for immature stages to complete their development (Aziz, 1985).

Table 4. Sub-lethal effect of the tested treatments on egg hatchability of spider mite *T. urticae* at 22ºC.

Treatment	Unhatched at indicated day					Grand mean
	1st day	2nd day	3rd day	4th day	5th day	
S bulk	14.29^{e}±0.137	12.28^{d}±0.092	7.43^{d}±0.256	5.35^{c}±0.037	3.26^{c}±0.145	8.51^{e}±0.065
S NPS	18.70^{d}±0.177	16.56^{c}±0.127	10.56^{c}±0.130	5.03^{c}±0.082	2.41^{d}±0.092	10.65^{d}±0.047
Ab- S bulk	21.64^{b}±0.076	18.51^{b}±0.081	17.45^{a}±0.223	15.44^{a}±0.131	11.51^{a}±0.229	16.91^{b}±0.083
Ab- SNPs	22.68^{a}±0.033	21.40^{a}±0.156	18.27^{a}±0.352	15.81^{a}±0.577	12.11^{a}±0.388	18.05^{a}±0.267
Ab	20.30^{c}± 0.120	16.32^{c}±0.095	14.28^{b}±0.363	10.77^{b}±0.316	9.29 ^{b}±0.137	14.19^{c}±0.081
Control	11.27^{f}±0.112	9.35^{e}±0.0550	7.44^{d}± 0.013	3.51 ^{d}±0.028	0.73^{e}± 0.146	6.46^{f}±0.0176
L.S.D.0.05	0.325	0.340	0.855	0.826	0.708	0.378

Table 5. Sub-lethal effect of the tested treatments on egg hatchability of spider mite *T. urticae* at 28 ºC

Treatment	Unhatched at indicated day					Grand mean
	1st day	2nd day	3rd day	4th day	5th day	
S bulk	11.29^{e}±0.137	9.29^{d}±0.185	5.27^{d}±0.192	3.69^{c}±0.093	2.51^{d}±0.366	6.41^{e}±0.09
S NPS	15.70^{d}±0.177	14.66^{b}±0.646	10.85^{c}±0.579	4.08^{c}±0.038	1.37^{e}±0.089	9.33^{d}±0.111
Ab- S bulk	18.64^{b}±0.076	16.18^{a}±0.269	14.38^{b}±0.138	12.97^{a}±0.315	8.92^{b}±0.075	14.22^{b}±0.066
Ab- SNPs	19.68^{a}±0.033	16.57^{a}±0.158	15.47^{a}±0.088	13.60^{a}±0.239	10.04^{a}±0.381	15.07^{a}±0.114
Ab	17.30^{c}±0.120	13.16^{c}±0.070	11.44^{c}± 0.288	7.77^{b}±0.316	6.29^{c}±0.137	11.19^{c}±0.042
Control	8.47^{f}±0.251	6.29^{e}±0.089	4.40^{d}±0.180	2.45^{d}±0.193	0.20^{f}±0.063	4.36^{f}±0.137
L.S.D. 0.05	0.411	0.842	0.983	0.703	0.767	0.330

Table 6. Sub-lethal effect of the tested treatments on duration (in hours) of *T. urticae* developmental stages at 22 and 28 ºC.

Treatment	Egg to larvae(Incubation period)		Egg to protonymph		Egg to deutonymph		Egg to adult	
	22	28	22	28	22	28	22	28
S bulk	217.92^{e}±1.05	108.53^{d}±0.86	249.75^{e}±0.67	143.22^{e}±0.54	312.09^{e}±1.30	164.5^{e}±0.57	350.78^{e}±0.56	221.89^{e}±0.72
S NPS	245.02^{d}±1.27	122.36^{c}±1.20	286.60^{d}±0.53	165.30^{d}±0.95	350.37^{d}± 0.80	182.43^{d}±1.36	376.52^{d}±0.47	252.87^{d}±1.42
Ab- S bulk	253.49^{b}±1.41	137.10^{b}±1.42	303.13^{b}±1.45	186.42^{b}±1.03	388.10^{b}±1.33	206.65^{b}±1.47	435.15^{b}±1.05	276.78^{b}±0.67
Ab- SNPs	275.12^{a}±0.60	144.05^{a}±1.60	312.97^{a}±1.42	194.18^{a}±0.83	402.56^{a}±1.37	223.11^{a}±1.50	457.70^{a}±1.23	284.69^{a}±2.05
Ab.	249.27^{c}±0.76	133.48^{b}±1.54	292.39^{c}±1.60	175.63^{c}±1.25	363.6^{c}±1.56	190.37^{c}±0.45	401.31^{c}±0.60	266.37^{c}±0.54
Control	185.65^{f}±0.24	94.78^{e}±0.39	224.31^{f}±0.33	132.27^{f}±1.22	277.91^{f}±0.90	151.03^{f}±0.44	331.56^{f}±0.61	209.01^{f}±0.29
L.S.D. 0.05	1.528	4.088	3.159	3.165	3.951	3.510	2.747	3.310

Discussion

By the time flow, all tested compounds impaired egg deposition and hatchability, according to earlier findings. Some researchers discovered similar results to the current experiment (Hosny; *et al.* 1998; Saadoon; 2006; Ismail *et al.* 2007; Hosny *et al.* 2009 and 2010; Keratum, 2010 Abdel-Halim, and Kalmosh; 2019). *T. urticae* egg hatchability was found to decrease with an increasing period of egg on the same disc (Hosny *et al.* 1998). The finding of Saadoon, 2006 that abamectin reduced the average number of eggs per female. Ismail *et al.* 2007 discovered that abamectin significantly reduced female fecundity and killed offspring of *T. urticae*. Also, Hosny *et al.* 2009 and 2010 discovered that ethion and abamectin had roughly the same ovicidal effect on spider mite eggs. Because of its antifeeding properties, abamectin deposits reduced oviposition in *T.urticae* (Keratum, 2010). Four-day-old eggs were significantly more sensitive to abamectin than one-day-old eggs. When applied directly to the egg of *T. urticae*, according to Abdel-Halim and Kalmosh 2019, spraying abamectin and/or nano-abamectin reduced mite fecundity compared to the water-sprayed control group, which showed deposition and hatched.

This study found that Ab-SNPs in nano-formulation had a greater effect on mite populations than abamectin alone. This discovery can be attributed to nanoscale chemicals having the ability to be more stable, penetrate, and adhere to treated surfaces, resulting in greater efficiency and residual effects (Gavanji *et al*., 2013). Abd El Rahman, 2017 stated that nano-particles of abamectin benzoate were the most toxic compound to adult female *T. urticae*. In fact,

nano-enhanced insecticides improve their stability on treated plants and become more potent. Furthermore, abamectin-grafted-N, O-carboxymethyl chitosan outperformed abamectin technical material against carmine spider mites (Li *et al*.,2016). The bounded groups may increase the compound's photostability and act as an antioxidant, capturing the hydroxyl radical in the aqueous solution (Guo *et al*., 2008). Abdel-Halim and Kalmosh, 2019 demonstrated that nano-acaricide had many times the bioactivity of conventional acaricide against the mite *T. urticae* (Koch). Spraying abamectin and/or nano-abamectin reduced mite fecundity when compared to the water-sprayed control group, which showed egg deposition and egg hatching. Several studies have found that different forms or derivatives of abamectin are more effective at reducing female fecundity in mites. The current study's findings are consistent with those of Abd El-Rahman, 2017 who found that abamectin nanoparticles were the most effective at reducing mite fecundity by 82.24 % percent. However, the common abamectin solution was less effective on egg hatchability (35 percent). Abdel-Halim, 2019 demonstrated that in a laboratory test, nano-abamectin was 30 times more toxic to adult female *T. urticae* (Koch) than abamectin. Furthermore, nano-abamectin reduced mite fecundity at higher levels than abamectin. Thus, the main advantage of using nano-based pesticides is the ability to improve properties such as efficacy and specificity. It can be used to deliver DNA and other desired chemicals into plant tissues in order to protect host plants from insect pests (Torney, 2009 ; Vinutha *et al.*, 2013).

According to these findings, it is clear that SiO_2 could be chosen as a suitable agent to control this pest. This should be done to determine whether or not the silica nanoparticles can act as an ovicidal agent against *T. urticae* populations under control. Our findings are consistent with those of other researchers (Stadler *et al*. 2010; Debnath *et al*., 2011; Rouhani *et al.* 2011; Zayed, 2016; Feng, *et al*., 2020 and Emam *et al*., 2021). Stadler *et al* (2010)'s finding is also consistent with our findings. They showed that alumina nanoparticles have an insecticidal effect on *Sitophilus. oryzae* and *Rhyzopertha Dominica* (Fabricius). According to Debnath *et al*. (2011), the hydrophilic and hydrophobic properties of SiO_2 had a significant impact on the mortality of *Sitophilus oryzae*. Furthermore, Rouhani *et al*. (2011) discovered that ZnO-TiO2-Ag nanoparticles have insecticidal activity against *Frankliniella occidentalis* (Pergande). In addition, Zayed, 2016 demonstrated the acaricidal activities of S bulk and SNPs against *T. urticae* in the field. Meanwhile, Feng *et al*. 2020 studied the biological activity survey for abamectin-loaded Mesoporous silica nanoparticles (MSNs) and revealed that they had excellent toxicological properties against *Plutella xylostella* larvae and maintained biological activity until the 15th day, with 70% mortality of the target insect. Furthermore, Emam *et al*. 2021 reported that SNPs disrupted all immature stages of T. urticae, resulting in a sharp decrease in the average number of eggs through 96h, at 1000 and 1500 ppm.

In terms of silica nanoparticles, *T. urticae* management has typically relied on the use of synthetic insecticides, and long-term usage of these chemicals leads to pesticide resistance. Nanoparticles have garnered a lot of interest in recent years for reducing diseases in agriculture (Guan *et al*., 2008; Sang Woo *et al*., 2009; Eleka *et al*., 2010). The application of nanomaterials in agriculture is still in its early stages. A comparison of our findings with previous research (Debnath *et al*., 2011) shows that using SNPs can greatly boost the mortality impact by increasing the period after application. They showed that SNPs have a lot of promise as a pesticide. This might be one of the reasons why there has been a long-standing practice of employing silica dust as a protective agent all throughout the world (Rouhani *et al*., 2012). Since of these NP features, SNPs were chosen for this investigation because they are inexpensive, stable, and pathogen-sensitive. Taking this into account, we estimate that abamectin will bond with the Si atoms at the SIO2 crystal surface to form a composite structure, causing additional harmful effects (Li *et al.*,2005). Or to surface swelling of the integument as a result of dehydration or occlusion of the examined insect's spiracles and tracheas. It also refers to their significantly enlarged exposed surfaces, which may interact with the insect cuticle.

Both sorption and abrasion damage the insects' protective wax covering on the cuticle. Examples of such processes include reactive oxygen types production, oxidative stress, membrane disruption, protein unfolding, and/or inflammation (Feng *et al*., 2000; Samuel & Guggenbichler, 2004; Elchiguerra *et al.*, 2005; Reddy *et al*., 2007; Donaldson *et al.*, 2009; Meng *et al*., 2009).

The use of SNPs increased abamectin activity more than S bulk, which could be attributed to two primary factors that cause nanomaterials to behave significantly differently than bulk materials: Surface effects (causing smooth properties scaling due to the fraction of atoms at the surface) and quantum effects (showing discontinuous behavior due to quantum confinement effects in materials with delocalized electrons) Roduner, (2006).

These parameters influence materials' chemical reactivity as well as their mechanical, optical, electric, and magnetic characteristics. (Rai *et al*., 2014) shown that nanoparticles that pierce the exoskeleton of insects attach to sulfur from proteins or phosphorus from DNA, causing organelles and enzymes to be rapidly damaged. Cellular function is damaged and the cell dies as a result of the decrease in membrane permeability and disruption in the proton motive force. Several nanoparticles can cross the blood-brain barrier and reach the central nervous system, according to (Jiang *et al.*, 2015; Benelli 2016). These nanoparticles were treated with an organic surfactant, allowing them to dissolve in an organic solvent (Zhang *et al.*, 2004) increasing a carrier's ability to load a hydrophobic medication because aggregation will not squander the huge surface-to-volume ratio The increasing biological efficacy of abamectin-loaded silica nanoformulation may be connected to the nano size, which is discussed at the beginning of the study. Second, as revealed, silica nanoparticles have pesticide action (Goswami *et al.*,2010).

The findings also imply that the effect of temperature on development is to cause an equal amount of change in each stage. When studying biological control systems, the proportion of total time spent in each step is critical. The idea proposed that the impact of varied temperature treatments may be due to cell division suppression, as all somatic cells are generated in the larval instars and any increase in mite size is a consequence of cell

size growth. If cell division was the determining factor, one would anticipate the stages with the highest cell division (i.e., the egg and larva) to be most influenced. The process is also unlikely to be feeding because, while the duration of the non-feeding stage (egg) was significantly reduced, the degree of feeding in the active immature stages varied significantly (Abd El-Rahman and El-Tahawe, 2017; Nizam *et al.*, 2017) and one would not expect exactly comparable effects to be exerted on different levels of feeding. We hypothesized that these effects could be caused by "hormotigoses" or the stimulation of metabolic processes by little amounts of stressful testing substances. The current study's findings are likely to have a similar rationale. The antifeeding characteristics of some drugs, particularly the parathyroid, are known to disrupt oviposition in mites, which will indirectly affect egg-laying.

To go forward with the actual application of SiO_2 nanoparticles and test agents as a new pesticide, more study on the safety of these materials for human health is necessary. Our findings are consistent with those of (Hussien *et al.*, 2021), who proposed that the usage of SNPs at 5 ppm can be employed as an eco-friendly management technique for *T. urticae*. Other aspects that need to be addressed include its method of action and the creation of formulations to increase potency and stability while also lowering costs.

CONCLUSION

The aim of this study was to look at the expanded role of silica nanoparticles SNPs as well as new active compounds against *T. urticae*. These compounds showed promise as *T. urticae* control alternatives to several potentially toxic conventional acaricides. Finally, an effective abamectin nanoformulation was created employing silica nanoparticles as a carrier. As a result, we present important fundamental data for future uses of nano insecticides in this work. Furthermore, they may have higher acaricidal action than standard abamectin.

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تعزز النانو سيلكا النشاط الإبادي الأكاروسي للأبامكتين ضد الأطوار غير الكاملة للعنكبوت الأحمر ذو البقعتين تيترانكيس أورنيكا

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أجريت الدراسة الحالية لتقييم تأثير التركيزات تحت المميتة لأربع مواد [سيلكا بلك ،سيلكا نانو برتكل ،مادتين مخلقتين (سيلكا-ابامكتين،سيلكا نانو-أبامكتين)] مقارنة بالمبيد الأكاروسي المخلق (أبامكتين) ضد الأطوار غير الكاملة للأكاروس تترانكس اورتيكا تحت الظروف المعملية. تم قياس التركيزات تحت المميتة للمواد المختبرة ضد الإناث البالغة للعنكبوت الأحمر بإستخدام الطرق القياسية للتقييم الحيوي. تم تقدير تأثير التركيزات تحت المميتة للمواد المختبرة علي وضع وفقس البيض تحت درجة حرارة ٢٢ و٢٨ علي التوالي. تم قياس تاثير المواد المختبرة علي تطور العنكبوت الأحمر بالساعات علي درجتي حرارة ٢٢و ٢٨ علي التوالي. أظهرت النتائج أن النانو سيلكا له نشاط إبادي معنوي ضد مراحل تطورالعنكبوت الأحمر. علي نفس النحو،كانا (نانوسيلكا- أبامكتين) أكثر المعاملات تاثيراً ضد وضع البيض وفقس البيض للتترانكس اورتيكا خلال خمس أيام علي درجتي حرارة ٢٢ و ٢٨ علي التوالي يليه أبامكتين تحت الظروف المعملية. أيضا أظهر نانوسيلكا- أبامكتين تاثيراً أعلي من المواد المختبرة علي مراحل تطور العنكبوت الأحمر علي درجتي حرارة مختلفتين. تقترح هذه الدراسة إمكانية استخدام سيلكا، سيلكا نانو كبدائل للمبيدات التقليدية وإدراجها ضمن ممارسات إدارة الآفات المتكاملة. فقد تساهم في التطبيقات المستقبلية لمكافحة الآفات من أجل الزراعة المستدامة.