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Article

Silicon derivatives induced host plant resistance against *Tetranychus urticae* (Acari: Tetranychidae) in eggplants farms

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ABSTRACT
A field experiment was conducted to evaluate the effect of silicon (Si) in the forms of oligomeric silicic acid (OSAB®) and potassium silicate (Silica K®) in inducing the resistance of eggplant *Solanum melongena* against *Tetranychus urticae* (Acari: Tetranychidae) infestation. Both forms were applied as a foliar spray at concentrations of 2 mL L^{-1} and 4 mL L^{-1}, respectively, with three sprays with an interval of 20 days between the three consecutive applications. *Tetranychus urticae* adult, nymph, and egg counts were recorded 10, 30 and 50 days after spraying (DAS). The effect of the two tested forms on *S. melongena* defense response was assessed by measuring the activity of enzymatic and non-enzymatic antioxidants. Our results showed that both Si forms at a high concentration (4 mL L^{-1}) significantly decreased the *T. urticae* stage numbers in *S. melongena*-treated plants. In addition, the Si-treated plants with the lowest *T. urticae* infestation were associated with increased Si leaf content, total phenol, and protein contents, as well as increased activity of the antioxidant enzymes compared to the control group. Si leaf content was negatively correlated with the *T. urticae* population density in *S. melongena*-treated plants with both tested treatments. In addition, a positive correlation was found between the Si leaf content and the activity of the antioxidant enzymes, total phenol, and protein contents. Applying both Si forms resulted in a positive effect in reducing the *T. urticae* infestation and its damage to *S. melongena*. Therefore, Si could be used as a foliar treatment to induce resistance in *S. melongena* plants, making it a potentially valuable pest management tool.

KEY WORDS: Antioxidant enzymes; induce resistance; silicon; *Solanum melongena*; two-spotted spider mite.

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INTRODUCTION

Eggplant (*Solanum melongena*, Solanaceae) is an economically important crop in Egypt and worldwide. Egypt ranks third in the global eggplant production, with a total production of 1.34 million tons from 0.049 million hectares. The total global production of eggplant is 56.62 million tons from 1.88 million hectares (Faostat 2020).

The two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) is the most common pest in Egyptian eggplant farming in all regions (Basha *et al*. 2021). *Tetranychus urticae* feeds primarily on the lower surface of the leaf, sucking the content of the mesophyll cells, and this is where the plant-mite interactions begins. This feeding results in the depolarization of the cell membrane, ion imbalance, and production of reactive oxygen species (ROS). An elevated level of

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ROS inside the cell, specifically H_2O_2, is toxic to plants, resulting in oxidative damage and cell death (Bensoussan *et al*. 2016). Consequently, plants evolved their antioxidant defense systems to alleviate cell damage caused by ROS by increasing the synthesis of non-enzymatic antioxidants [photosynthetic pigments, protein, and phenolic compounds] as well as other enzymatic antioxidant defenses [superoxide dismutase (SOD), peroxidase (POD), catalase (CAT), glutathione peroxidase (GPx), and polyphenol oxidase (PPO)] (Valko *et al*. 2007; Sereme *et al*. 2016; Golan *et al*. 2019). POD accelerates the oxidoreduction of H_2O_2 and phenolic compounds. Furthermore, it plays a crucial role in the suberization and lignification of the cell wall building processes producing lignin. Lignin plays a crucial role in the plant defense process, strengthening the host's cell walls (Peyrano *et al*. 1997; Hiraga *et al*. 2001). PPO also contributes to the lignification process and is necessary to accelerate the oxidation of phenols to quinones complexed with proteins, thus reducing the nutritional content of food and making protein digestion harder (Mohammadi and Kazemi 2002). CAT detoxifies H_2O_2 by converting it into water and oxygen (Arbona *et al*. 2003; Valko *et al*. 2007; Cuypers *et al*. 2011).

Plant resistance inducers are one of the pesticide-free, environmentally friendly approaches to pest population reduction (Alhousari and Greger 2018). Silicon (Si) has become the focus of interest as it is thought to be a beneficial element to plants. Si application was found to increase plant growth, biomass, photosynthetic pigments, straw and grain yield, and quality as well as improved soil structure, especially under biotic and abiotic stresses (Coskun *et al*. 2016; Walsh *et al*. 2018; Jeer *et al.* 2021). Several studies have demonstrated the importance of Si as a beneficial element and as a resistance-inducing agent against pests when Si is supplied in high concentrations (Massey *et al.* 2007; Ranger *et al*. 2009; Hou and Han 2010; He *et al.* 2015; Singh *et al*. 2020).

The defense mechanisms of Si against alleviation of insect pest damage work via two main defenses; the first physical defense involves increasing hardness and abrasiveness of plant tissues impedes insect feeding by disrupting chewing, penetration, and digestion due to increased Si deposition in tissues. Second, triggering biochemical defense pathways by regulating defense-related enzymes (POD, PPO, and chitinase), plant hormone signaling, and change of plant volatile mixtures (Massey and Hartley 2009; Bhatt and Sharma 2018; Islam *et al*. 2020), and this effect was due to high Si levels in the plants (Liang *et al.* 2003; Correa *et al.* 2005; Cai *et al.* 2008; Rizwan *et al*. 2015; Reynolds *et al.* 2016). Since Si leaves have not shown any pesticide residues in food or the environment, it is a promising component of the integrated pest management of insect pests and can be definitely incorporated with other pest management tactics (Laing *et al*. 2006).

Few studies have focused on Si-induced alterations in the defense system of *S. melongena* resistance during *T. urticae* infestation. The current study hypothesized that Si could improve the *S. melongena* resistance against *T. urticae* infestation by influencing the mite population dynamism and activity of antioxidant enzymes and the levels of non-enzymatic antioxidants.

Since most foliar Si studies used only potassium silicate, different Si forms and concentrations are required. Oligomeric silicic acid is a new Si formulation, and few studies have been conducted to assess its effects on eggplant. Accordingly, the experiment was conducted to investigate whether the foliar Si application in the form of oligomeric silicic acid and potassium silicate would induce the resistance of *S. melongena* against *T. urticae* infestation.

MATERIAL AND METHODS

Experimental design and treatments

The experiment was carried out during the growing season 2019–2020 at the experimental farm of Ismailia Agricultural Research Station, ARC, Ismailia Governorate (32° 14′ 50″ E and 30° 35′ 30″ N).

In the present study, two forms of Si were utilized comprising of the oligomeric silicic acid (OSAB®) (2.5% oligomeric silicic acid (Si: 0.8%) in combination with 1.2% potassium chloride

(KCl), 0.8% Boron (B: 0.2%), 47.0% Demi water and 47.5% PEG_{400} (stabilizer)) obtained from Rexil-Agro BV Company (Co.) (Netherlands). The potassium silicate (Silica K®) (SiO_2: 22%; K_2O: 11%) was obtained from Techno-green Co. (Egypt).

Eggplant seedlings "cv. Anamour" were sown in experimental plots (each plot represents a replication) that had a raw spacing of 60 cm and a plant spacing of 30 cm. Treatments were arranged in a Randomized Complete Block Design (RCBD) with three replications (30 plants per treatment). The treatment concentrations 2 mL L^{-1} and 4 mL L^{-1} were selected after preliminary bioassays to define the response range/safe concentrations. Thirty days following transplantation, the Si treatments were initiated by applying the two concentrations with three sprays with an interval of 20 days between the three consecutive applications as recommended by the producer company. The control group did not receive any silicon addition. A 5L handheld pressure sprayer at 3 bar pressure (Homdum, China) was used for foliar Si applications prior to mite appearance. Fertilization, irrigation, and other agricultural practices were performed according to the Egyptian Ministry of Agricultural and Land Reclamation protocol as follow: 317.26 Kg N/ha as 1547.62 kg ammonium sulfate (20.5% N), 228.57 kg K_2O/ha as 476.19 Kg potassium sulfate (48% K_2O), and 147.62 kg P_2O_5/ha as 952.38 Kg calcium superphosphate (15.5% P_2O_5).

After the last Si spray, 15 leaves per replicate covering the top, middle, and bottom of each treatment were randomly collected 10, 30, and 50 days later for *T. urticae* monitoring. The number of adults, nymphs, and eggs was counted in a 2.5 cm^2 area on the underside of the leaf according to Kumar *et al*. (2015) under a Stereo-Binocular microscope (Olympus SZ-PT, Japan).

Assay of enzymatic and non-enzymatic antioxidants

Some biochemical analyses were carried out to assess the *S. melongena* defense system. Five mature fresh leaves and the fourth leaf were randomly collected from each treatment group 50 days after the last Si spray for Si leaf content analysis and the other analyses, respectively. The UV-Vis spectrophotometer (Spectronic, 1201, Milton Roy, USA) was used to monitor all activity measurements.

Fresh leaves (0.5 g) were stored at −20 °C and processed for the extraction assay as described by Hildebrand *et al*. (1986). The catalase activity was measured according to the method described by Aebi (1984), in which the decomposition of hydrogen peroxide was monitored spectrophotometrically at 240 nm. The peroxidase activity was determined directly, as described by Langcake and Wickins (1975), by monitoring the increase in absorbance at 420 nm. The polyphenol oxidase activity was evaluated according to the method described by Ishaaya (1971) by monitoring the increase in absorbance at 410 nm.

Si leaf content determination

A modification of the autoclave-induced digestion (AID) method, as described by Elliott and Snyder (1991), was used to extract Si from strawberry leaves [oven-dried (at 65 °C) leaf powder (0.1 g)]. After digestion, the Si content was measured using the colorimetric amino molybdate blue color method (Jones 1984). A Si standard curve was constructed to calculate the concentration of Si in all the treated and untreated leaves. The Si content of the sample material was then calculated using the equation $Y = 0.0036\ x$, where y is the absorbance of Si at 650 nm, and x is its concentration (mg L^{-1}).

Total protein content determination

The total protein content was determined by the dye-binding method (Bradford 1976) using bovine serum albumin as a standard, and the absorbance was measured at 595 nm.

Total phenol content determination

The total phenol content was determined using the Folin-Ciocalteu method (Singleton and

Rossi 1965) using gallic acid as the standard. The absorbance was measured spectrophotometrically at 765 nm.

Statistical analyses

Data analysis was performed using the analysis of variance (ANOVA) by SPSS version 23.0 (New York, NY, USA). Mean comparisons were performed using Tukey's Honestly Significance Difference (HSD) ($P \leq 0.05$). A Pearson correlation coefficient (r) and linear regression analysis were utilized to determine the relationship between the average Si leaf content and the pooled mean number of *T. urticae* per leaf, the activity of POD, CAT, and PPO, total phenol, and total protein contents. All values in the figures are expressed as the mean values ± standard errors (SE).

RESULTS

The effect of OSAB and Silica K foliar spraying on *S. melongena* plants with different concentrations was evaluated on the population density of the different stages of *T. urticae*. Figure 1 (A–C) shows the mean number (± SE) of *T. urticae* adult, nymph, and egg stages 10, 30, and 50 days after spraying (DAS). The obtained results indicated that both concentrations of OSAB and Silica K caused a significant reduction in the number of *T. urticae* adult, nymph, and egg stages compared to their corresponding control group. The lowest number of the adult stage was recorded at 50 DAS in plants treated with OSAB at 4 mL L^{-1} reaching (0.40 ± 0.13), while in plants treated with Silica K, it was recorded (0.93 ± 0.27) at the same concentration compared to the control group (6.67 ± 0.67) (Fig. 1A). At 30 DAS, both OSAB and Silica K at 4 mL L^{-1} showed the highest efficacy in reducing the nymph number (0.0 ± 0.0) than the control group (4.27 ± 0.47) (Fig. 1B). The lowest number of the egg stage was recorded at 50 DAS (1.87 ± 0.56) in plants treated with Silica K at 4 mL L^{-1} compared to the control group (14.80 ± 1.06) (Fig. 1C).

The effects of foliar spray with the different Si forms and concentrations on Si content in leaf, total phenol, and total protein contents as well as the activity of the CAT, POD, and PPO in *S. melongena* leaves, were shown in Figure 2. The Si leaf content was significantly high in plants treated with OSAB at 4 mL L^{-1} (121.00 ± 2.08 mg L^{-1}) and higher than in those treated with Silica K at the same concentration (97.00 ± 2.51 mg L^{-1}). There was a significant increase in Si leaf content in the group treated with the two Si forms compared with the control group ($P \leq 0.05$) (Fig. 2A). The total protein content was significantly high in plants treated with OSAB at 4mL L^{-1} (3.56 ± 0.15 mg g^{-1} FW) and higher than in the plants treated with Silica K at the same concentration (2.77 ± 0.09 mg g^{-1} FW). In contrast, the control group demonstrated the lowest total protein content (1.62 ± 0.3 mg g^{-1} FW) (Fig. 2A). The highest phenol content was recorded in plants treated with OSAB at 4 mL L^{-1} (1.92 ± 0.10 mg GAE g^{-1} DW) and Silica K at 4 and 2 mL L^{-1} (1.73 ± 0.04 and 1.70 ± 0.08 mg GAE g^{-1} DW, respectively), as compared to the control group. No significant differences were detected in phenol content between the control group and the plants treated with OSAB at 2 mL L^{-1}. The current study's results revealed no significant effect in phenol content between both Silica K concentrations, but the opposite was found in the plants treated with OSAB (Fig. 2A).

The highest POD activity was recorded in the plants treated with Silica K, followed by OSAB-treated plants at the highest concentration applied 4 mL L^{-1} (107.67 ± 3.71 and 92.67 ± 3.71 min g^{-1} FW, respectively). The lowest POD content was (64.10 ± 2.47 and 52.57 ± 1.29 min g^{-1} FW) recorded in the plants treated with OSAB at 2 mL L^{-1} and the control group, respectively (Fig. 2B). The plants treated with OSAB at 4 mL L^{-1} were found to be more elevated in CAT activity (4.52 ± 0.17 mM min^{-1} g^{-1} FW) than other treatments. The control group had the lowest CAT activity, followed by the plants treated with Silica K at 2 mL L^{-1}. No significant differences were observed in CAT activity between plants treated with OSAB at 2 mL L^{-1} and plants treated with Silica K at 4 mL L^{-1} (Fig. 2B). The highest PPO activity was recorded in plants treated with both OSAB and

Silica K at 2 and 4 mL L^{-1} without any significant differences compared to the control group (Fig. 2B).

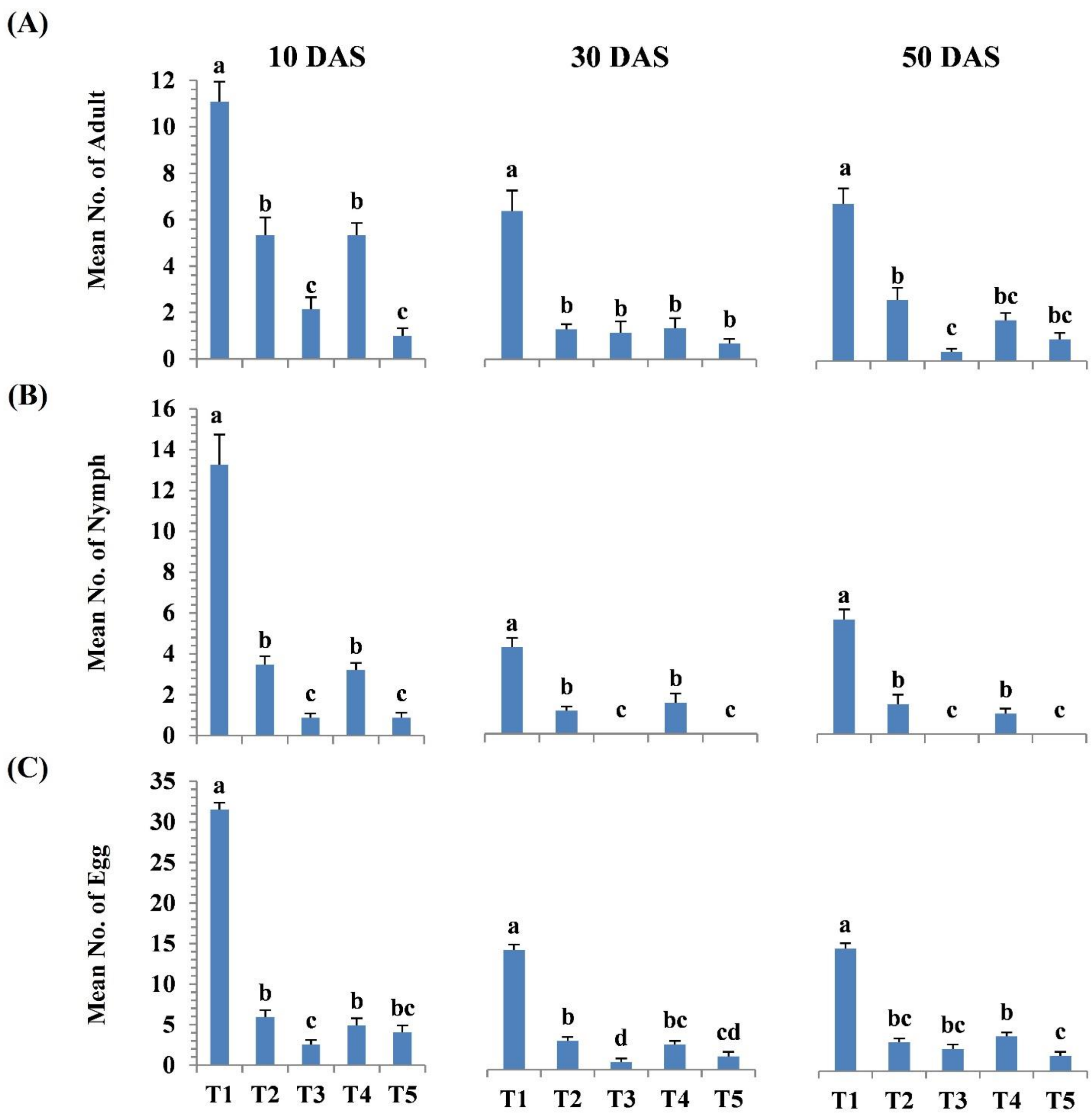

Figure 1. Mean number ± SE of the different stages of *T. urticae* on *S. melongena* leaves 10, 30 and 50 days after spraying (DAS). Means followed by the same letter are not significantly different using Tukey's HSD at $P < 0.05$. T1 = Control, T2 = OSAB 2 mL L^{-1}, T3 = OSAB 4 mL L^{-1}, T4 = Silica K 2 mL L^{-1}, and T5 = Silica K 4 mL L^{-1}.

The data displayed in Table 1 showed a significant negative correlation between Si leaf content and the pooled mean number of *T. urticae* population in *S. melongena*-treated plants by both OSAB and Silica K. The highest correlation coefficient between Si leaf content and *T. urticae* population density was found in plants treated with OSAB ($r = -0.988$; $P = 0.000$) than those treated with Silica K ($r = -0.791$; $P = 0.011$). However, a positive correlation was detected between Si leaf content and the activity of enzymatic antioxidants, total protein, and total phenol contents. The highest correlation coefficient between Si leaf content and PPO activity, total phenol, and total protein contents was found in plants treated with OSAB. While, the correlation coefficient between Si leaf content and the activity of POD and CAT was the highest in plants treated with Silica K.

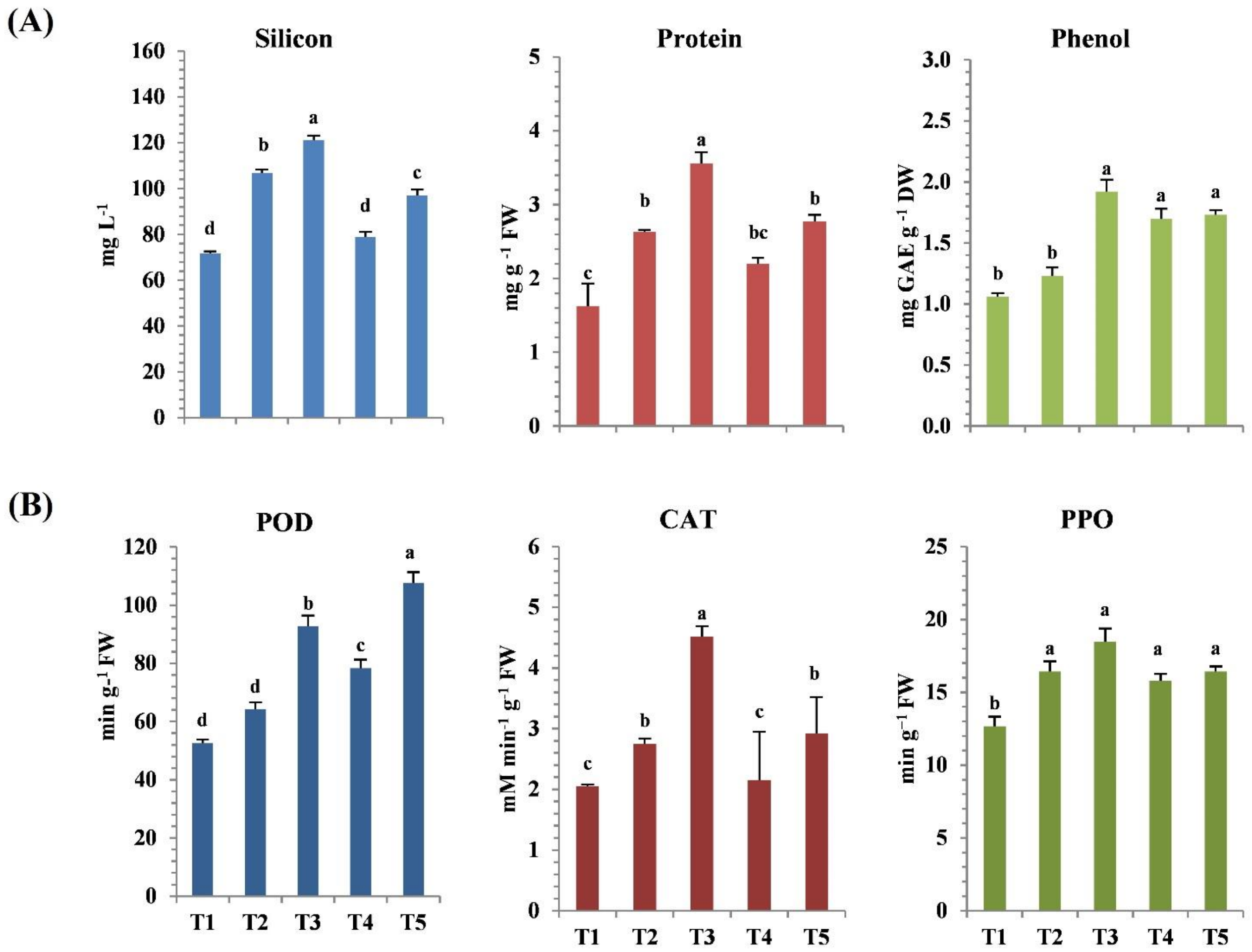

Figure 2. (A) Silicon leaf, total protein and phenol contents, (B) Activity of POD, CAT, and PPO of *S. melongena*-treated plants. Means followed by the same letter are not significantly different using Tukey's HSD Test at $P < 0.05$. T1 = Control, T2 = OSAB 2 mL L^{-1}, T3= OSAB 4 mL L^{-1}, T4= Silica K 2 mL L^{-1}, and T5 = Silica K 4 mL L^{-1}.

Table 1. Linear regression between Si leaf content and *Tetranychus urticae* population density, activities of POD, CAT, PPO, total protein and phenol contents of OSAB and Silica K-treated plants.

Parameters	OSAB			Silica K		
	R	R^2	Regression equation	R	R^2	Regression equation
T. urticae density	-0.988^{**}	0.975	y = −0.671x + 83.24	-0.791^{*}	0.625	y = −1.023x + 100.63
POD activity	0.857^{**}	0.734	y = 0.710x − 1.06	0.933^{**}	0.871	y = 1.940x - 80.64
CAT activity	0.866^{**}	0.749	y = 0.044x - 1.25	0.940^{**}	0.884	y = 0.034x − 0.42
PPO activity	0.896^{**}	0.802	y = 0.113x + 4.55	0.680^{*}	0.462	y = 0.111x + 5.79
Protein Cont.	0.918^{**}	0.842	y = 0.037x − 1.09	0.854^{**}	0.730	y = 0.042x − 1.29
Phenol Cont.	0.803^{**}	0.645	y = 0.015x − 0.08	0.676^{*}	0.457	y = 0.020x − 0.13

(*) Correlation is significant at the 0.05 level (2-tailed)
(**) Correlation is significant at the 0.01 level (2-tailed)
(R) Correlation coefficient, (R^2) Determination coefficient

DISCUSSION

One of the promising tactics compatible with sustainable agriculture is the application of Si for boosting plant resistance against diseases and insect herbivores in various agricultural crops (Guével *et al*. 2007; Massey and Hartley 2009). It is evident that Si is a phyto-beneficial element that increases plant yield and growth, as well as an improvement of photosynthetic pigments (Crusciol *et al*. 2013; Laane 2017, 2018; Bhatt and Sharma 2018; Walsh *et al*. 2018; Jeer *et al*. 2021; Karimian *et al*. 2021).

Studies using the foliar application of oligomeric silicic acid and potassium silicate in inducing *S. melongena* resistance against *T. urticae* remain scarce; however, they both act as resistance inducers (Du Jardin 2015; Vieira *et al*. 2016), increase Si leaf content (Crusciol *et al*. 2013; Felisberto *et al*. 2021), antioxidant enzymes' activities, protein and phenol contents of different crops (Ma 2004; Massey *et al*. 2006; Zhang *et al*. 2013). Some studies have used foliar application of potassium silicate and silicic acid to induce the resistance of different crops against mites and other pests. The application of potassium silicate increased the resistance of eggplant, maize, bean, and cucumber to control *T. urticae* infestation (Gatarayiha *et al*. 2010). In addition, Nikpay and Soleyman Nejadian (2014) detected a significant reduction in the sugarcane yellow mite *Oligonychus sacchari* (Acari: Tetranychidae) population density when treated with potassium silicate as compared to the control. Silicic acid application negatively affected the number of eggs and nymphs of the whitefly *Bemisia tabaci* and the tomato leaf miner *Tuta absoluta* decreasing their density (Melo *et al*. 2016; Alyousuf *et al*. 2022).

Our results revealed that both Si forms significantly lower the *T. urticae* stage numbers in *S. melongena*-treated plants. The lowest number of the adult and egg stages was observed at 50 DAS, while the lowest nymph stage number was at 30 DAS in plants treated with OSAB and Silica K at the highest concentration used (4 mL L^{-1}) as compared to the control group. Furthermore, the Si-treated plants with the lowest *T. urticae* infestation have been associated with increased total phenol and protein contents and increased the activity of PPO, POD, and CAT as compared to the control group. This finding may be due to the increased level of defense-related enzymes and production of secondary compounds (e.g., proteins and phenols) which in turn lead to an increase in their activity thus providing more plant adaptation against the infestation (Gomes *et al*. 2008; Ferreira *et al*. 2011). Si addition to *S. lycopersicum* can control *T. urticae* by providing direct/indirect defense via foliar application, as demonstrated by Faraone *et al*. (2020). Si addition increased activities of defense-related enzymes (SOD, POD, CAT, PAL, and PPO) and soluble protein levels in leaves of Si-treated plants causing a significant reduction of the rice leaf folder *Cnaphalocrocis medinalis* (Lepidoptera: Pyralidae), as reported by Han *et al*. (2016). Correa *et al*. (2005) investigated the effectiveness of Si application to induce resistance against *B. tabaci* infestation. They found that the number of *B. tabaci* nymphs on cucumber-treated plants was significantly lower than untreated ones, which may be related to several chemical defense inductions.

Plants contain a vast array of biochemical defenses against herbivores, including secondary metabolites that disrupt nutrient uptake by herbivores. The addition of Si simplifies the production of rich foliage in these secondary metabolites, thereby improving plant defense against pests (Reynolds *et al*. 2016). Our results showed that both OSAB and Silica K at 4 mL L^{-1} significantly increased the Si leaf content (121.00 ± 2.08 and 97.00 ± 2.51 mg L^{-1}, respectively) compared to the control group (71.67 ± 0.88 mg L^{-1}). Consequently, the lower abundance of *T. urticae* at the high Si concentration used may be due to higher levels of Si element in treated plants that increased the activity of CAT, POD, and PPO to alleviate cell damage caused by ROS as a result of mites feeding (Bensoussan *et al*. 2016; Golan *et al*. 2019). PPO and POD enhance the production of lignin deposited in the plant cell wall, increasing the leaf toughness, thus lowering the quality, efficiency, and absorption of food by insects and decreasing their performance and fecundity (Fawe *et al*. 1998; Rodrigues *et al*. 2004; Gomes *et al*. 2005; Johnson *et al*. 2009). Si may confer some protection against *T. urticae* infestation in monocotyledonous and dicotyledonous plants, mainly when applied as a foliar spray to raise the Si concentration in leaves (Gatarayiha *et al*. 2010; Ye *et al*. 2013; Nikpay and Laane 2020; Felisberto *et al*. 2021). Si is absorbed through the cuticle and deposited in the epidermal cell and cell wall. The rigidity and pectin content of the middle lamella act as a physical barrier to insect stylet penetration resulting in difficulty in pest feeding, thus affecting the completion of its life cycle as well as reducing the plant damage (Menzies *et al*. 1992; Han *et al*. 2016; Toledo and Reis 2018).

Therefore, applying both Si forms resulted in a positive effect in reducing the *T. urticae* infestation and its damage caused in the *S. melongena*. The current study revealed that Si may enhance the biochemical defenses of *S. melongena*. Moreover, the activation of defensive responses of plants is a promising tool for controlling pests in sustainable farming.

CONCLUSION

Foliar application of Si was significantly effective in reducing the population density of this key pest (*T. urticae*) attacking the *S. melongena* crop. In sustainable agriculture, using different silicon compounds is widely approved, and it might be considered a suitable, effective, and environmentally sound approach for eliminating biotic stresses (arthropod pests) in field conditions.

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مشتقات سیلیکون باعث ایجاد مقاومت گیاه میزبان در برابر *Tetranychus urticae* (Acari: Tetranychidae) در کشتزار بادمجان

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چکیده

آزمایشی مزرعه‌ای برای ارزیابی اثر سیلیکون (Si) در اشکال اسید سیلیسیک الیگومریک (OSAB®) و سیلیکات پتاسیم (Silica K®) در القای مقاومت به بادمجان *Solanum melongena* در برابر آلودگی به *Tetranychus urticae* (Acari: Tetranychidae) انجام شد. هر دو فرم به عنوان محلول‌پاشی در غلظت‌های ۲ میلی‌لیتر در لیتر و ٤ میلی‌لیتر در لیتر به ترتیب با سه محلول‌پاشی با فاصله ۲۰ روزه بین سه کاربرد پیاپی استفاده شد. تعداد کنهٔ کامل، پوره و تخم *Tetranychus urticae* ۱۰، ۳۰ و ۵۰ روز پس از سمپاشی (DAS) ثبت شد. اثر دو شکل آزمایش شده بر پاسخ دفاعی *S. melongena* با اندازه‌گیری فعالیت آنتی‌اکسیدان‌های آنزیمی و غیر آنزیمی ارزیابی شد. نتایج نشان داد که هر دو شکل Si در غلظت بالا (٤ میلی لیتر در لیتر) به مقدار زیادی تعداد را در مراحل *T. urticae* در گیاهان تیمار شدهٔ *S. melongena* کاهش دادند. افزون بر این، گیاهان تیمار شده با Si با کمترین آلودگی به *T. urticae* با افزایش محتوای Si برگ، فنل کل و محتوای پروتئین و همچنین افزایش فعالیت آنزیم‌های آنتی‌اکسیدانی در مقایسه با گروه شاهد همراه بودند. محتوای Si برگ با انبوهی جمعیت *T. urticae* در گیاهان تیمار شدهٔ *S. melongena* با هر دو تیمار آزمایش شده همبستگی منفی داشت. افزون بر این، همبستگی مثبتی بین محتوای Si برگ و فعالیت آنزیم‌های آنتی‌اکسیدانی، فنل کل و محتوای پروتئین مشاهده شد. استفاده از هر دو شکل Si منجر به اثر مثبت در کاهش آلودگی به *T. urticae* و کاهش خسارت آن به *S. melongena* شد. بنابراین، Si می‌تواند به صورت محلول‌پاشی روی برگ برای القای مقاومت در گیاه *S. melongena* استفاده شود و آن را به ابزاری بالقوه با ارزش در مدیریت آفات تبدیل کند.

واژگان کلیدی: آنزیم‌های آنتی‌اکسیدان؛ القای مقاومت؛ سیلیکون؛ *Solanum melongena*؛ کنهٔ تارتن دولکه‌ای.

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