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Env. Biodiv. Soil Security, **Vol. 5**, pp. 267-274 (2021)

Environment, Biodiversity & Soil Security
(EBSS)
http://jenvbs.journals.ekb.eg//

Nano-Silicon for Plant Biotic Stress: A Short Communication

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THE GLOBAL food production faces great threats including the changing in climate, and different environmental stresses, which may decrease it causing global food insecurity. So, many new approaches and technology are become crucial to solve this problem like nanotechnology. Nanofertilizers, like nano silica, have several benefits including higher use efficiency, improving nutrients uptake, higher plant growth and vigor, higher crop yield and its quality, reducing the environmental stress on cultivated plants, and higher economic feasibility compared to traditional fertilizers. Nano-silica (SiO_2-NPs), as less toxic and immensely stable, has several applications especially in the medicine and agricultural fields. Silica nanoparticles has been also applied for supporting cultivated plants under biotic/abiotic stress, the nano-remediation of the environment pollutants (like heavy metals, organic pollutants and radioactive compounds in soil and water), and water purification. This is a call by EBSS for different kind of articles including original articles, mini-review or reviews and others. The environmental dimension of silica nanoparticles in the medicine, industry, or agricultural fields has a great priority to publish beside other new approaches in the security of food, soil, water and energy.

Keywords: Nano-silica, Plant pathogens, Phytopathology, Salinity, Drought, Stress.

1. Introduction

Silicon (Si) could be categorized as "a quasi-essential nutrient" for plant nutrition due to their beneficial hormetic roles in growth of plants, development and its metabolism (Elsokkary 2018; Zargar et al. 2019; Arif et al. 2021). This element could uptake in form of silicic acid H_4SiO_4 not in form of SiO_2 (Gaur et al. 2020; Gómez-Merino et al. 2020) and this uptake mainly depends on plant species (ranges from 0.1% to 10% DW) and soil properties such as soil pH, soil texture, soil organic matter, soil microorganism and soil moisture content (Caubet et al. 2020; Schaller et al. 2021). There are some crops having high Si content and called "Si-accumulators", which include rice (4.18% DM Si), wheat (2.45%), barley (1.82%), sugarcane (1.60%), soybean (1.40%), and sugar beet (1.26%) (Gómez-Merino et al. 2020). Silicon also has regulatory role in mitigating plant nutritional stresses (Ali et al. 2020;

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Received 23/09/2021; Accepted 10/11/2021
DOI : 10.21608/jenvbs.2021.97644.1145

Ranjan et al. 2021) such as drought (Bukhari et al. 2020; Alam et al. 2021), salinity (Homann et al. 2020; Dhiman et al. 2021), heat stress (Khan et al. 2020; Shalaby et al. 2021), heavy metal stress (Li et al. 2020), and biotic stress (Islam et al. 2020), as well as the climate changes and environmental hazards (Bokor et al. 2021).

Nano-silica is considered an important nano-fertilizers or nanoparticles with highly reactive surface to volume ratios and their agro-applications are currently an interesting area of research (Rastogi et al. 2019; Akhtar et al. 2021). Nano-silica is well known as non-toxic nanofertilizer to soil microbial communities comparing with other silicon sources (Akhtar et al. 2021). Nano-seed priming using Si-NPs can mediate the growth, physiology and antioxidant metabolic status in plants (Asadpour et al. 2020; Siddiqui et al. 2020; Hatami et al. 2021; Mukarram et al. 2021). This enhancing role of nano-Si could be achieved alone or using added-material like chitosan-silicon as nanofertilizer (Kumaraswamy et al. 2021) or potassium silicate (Felisberto et al. 2020). The crucial application of nano-Si is to facilitate plant growth and stress tolerance (Mathur and Roy 2020) such as drought (Namjoyan et al. 2020; Esmaili et al. 2021), salinity (Naguib and Abdalla 2019), heavy metal stress (Emamverdian et al. 2020; Memari-Tabrizi et al. 2021), and treatment of bacterial infections (Selvarajan et al. 2020) or against plant pathogens (Wang et al. 2021a).

Therefore, this is a call for more articles concerning the beneficial roles of nano-Si in mitigating different biotic stresses including plant pathogens and many phytopathology. This call also welcomes original articles, reviews, mini-reviews, and short communications including the physiological, biochemical, molecular aspects. The co-impact of anno-Si and other nano-fertilizers especially under combined stresses including biotic and/or abiotic stresses.

2. Nano-Si for stressful plants and pathogens

Silica nanoparticles or SiO_2-NPs have become benefits, which represent in several applications including agro-applications (nanofertilizer, nano-pesticides, nano-remediator, and nano-ameliorator), nano-structuring, biomedical or drug delivery, and optical imaging agents (Table 1 and Figs. 1-4). Silica-NPs are immensely stable, less toxic, and has been applied for soil and water remediation from the environment pollutants (e.g., organic pollutants, heavy metals and radioactive compounds into water), removing pollutant of metals, and radioactive elements, as well as water purification (Jeelani et al. 2020). Concerning the main application of nano-silica in agricultural field, it might use as nano-pesticides to reduce using of traditional chemical pesticides in the agriculture, which cause a damage in the agriculture leading to the exhaustive decrease in crop yields (Wu and Li 2021). Due to the heavy usage of conventional chemical pesticides, which penetrated and degraded huge areas of soils and polluted ground waters, imbalanced nutrients and unproductive lands have been resulted causing many problems for health and environmental issues (Jeelani et al. 2020). Nano-silica as dual-use materials, can provide essential elements and induce bio-stimulation for plants, as well as nanomaterials, which may not categorize as nano-fertilizers inducing bio-stimulation and can be combined with bulk fertilizers as nano-additives (Hu and Xianyu 2021; Naz and Benavides-Mendoza 2021). The distinguished roles of nano Si in mitigation abiotic and/or biotic stresses are reported in some published studies in Table 1.

3. Nano-Silicon: A call for papers

In this short communication, a call for submission of different kind of articles (original articles, mini-review, review, comments and notes) focusing on the nano-Si and its application fields particularly under biotic stress. This call aims for more comprehensive overviews on the interplay between Si-NPs and different cultivated plants under biotic stress from two aspects: how Si-or SiO_2-NPs serve for plants where these NPs can act mainly as nano-pesticides, nano-fertilizers, nano-antimicrobial agents, nano-biosensors and plant mimics; and the second is how cultivated plants can grow and develop under different stresses. Several open questions still need to be answered concerning the role of nano-Si under plant biotic stress like what is the expected interaction between nano-Si and other nanoparticles in soil under plant stress? What are the main factors controlling this interaction in soil? What are the expected effects of this interaction on soil microbial community and enzyme activities?

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

TABLE 1. Recent published studies on nano-silicon roles under different stressful plant species

Main findings of the study(s)	Reference(s)
Some published studies on biotic stress	
Applied nano-chelated silica-fertilizer was an effective and safe pest control (root-knot nematodes) by preventing and reducing of the losses of tomato production under greenhouse conditions	Charehgani et al. (2021)
Silica-NPs enhanced watermelon fruit yield by 81.5% compared to control, which lead to suppress *Fusarium* wilt disease (*Fusarium oxysporum* f. sp. *niveum*) and plant health	Kang et al. (2021)
Enhancing maize resistance against oriental armyworm by applying 50 mg L^{-1} Si nanodots by activating the biosynthesis of chemical defenses (e.g., chlorogenic acid, total phenolics)	Wang et al. (2021a)
Applied soil of nano silica increased the insecticidal activity of maize against some stored insects after the postharvest	El-Naggar et al. (2020)
Foliar applied SiO_2-NPs mitigated the chilling effects on sugarcane by enhancing photosynthesis and photoprotection	Elsheery et al. (2020)
SiO_2-NPs seed priming and *Rhizobium leguminosarum* in combination increased the growth of pea and bacterial blight disease caused by *Meloidogyne incognita* and *Pseudomonas syringae* pv. pisi. Arch	Kashyap and Siddiqui (2020)
Nano-management the growth of sugar beet diseases including the white Chitwood (*Meloidogyne incognita*), *Pectobacterium betavasculorum* and *Rhizoctonia solani* disease complex	Khan and Siddiqui (2020)
Nano-management of many carrot diseases by SiO_2-NPs like bacterial soft-rot (*Pectobacterium carotovorum*), bacterial leaf blight (*Xanthomonas campestris* pv. carotae), fungal leaf blight (*Alternaria dauci*) and crown rot (*Rhizoctonia solani* Kuhn)	Siddiqui et al. (2020)
Some published studies on abiotic stress	
Nano-Si has a crucial role in mitigating changing environments	El-Ramady et al. (2018); Rajput et al. (2021)
Synergistic effect of nano-Si in fighting against drought stress	Namjoyan et al. (2020); Akhtar et al. (2021); Afshari et al. (2021); Esmaili et al. (2021)
Nano-Si for fighting against salinity stress	Mahmoud et al. (2020); El-Saadony et al. (2021)
Beneficial effect of nano-Si against increased UV-light exposure	Tripathi et al. (2017)
Beneficial effect of nano-Si against temperature stress including heat stress, chilling stress and freezing stress	Elsheery et al. (2020)
Nano-Si for remediation the contaminated soil and/or agro-wastewaters with metals/metalloids	Akhayere et al. (2019); Zuo et al. (2020); Lian et al. (2021); Wang et al. (2021b)
Nano-Si for mitigating heavy metal stress on cultivated plants	de Sousa et al. (2019); Banerjee et al. (2021); El-Saadony et al. (2021); Zhou et al. (2021)
Beneficial effect of nano-Si against waterlogging stress	

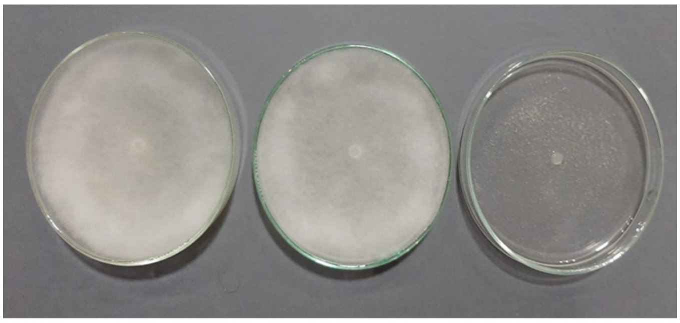

Fig. 1. Effect of applied nano-silicon on *Pythium* spp. in most vegetables causing the *Pythium* root rot or damping off

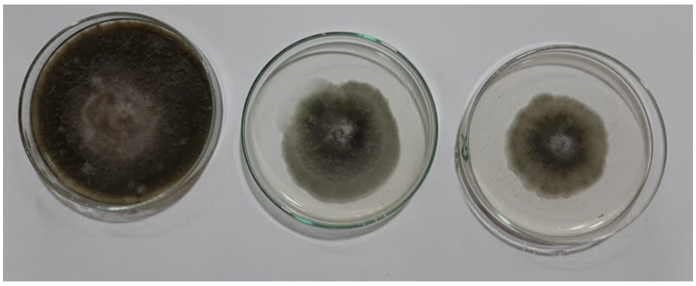

Fig. 2. Impact of nano-silicon on *Alternaria solani* as a disease in tomato and potato plants called early blight

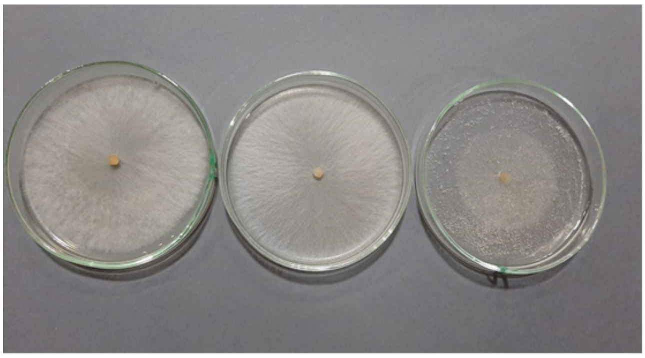

Fig. 3. Effect of nano-silicon on *Rhizoctonia solani*, which causes the damping off or root rot or stem rot

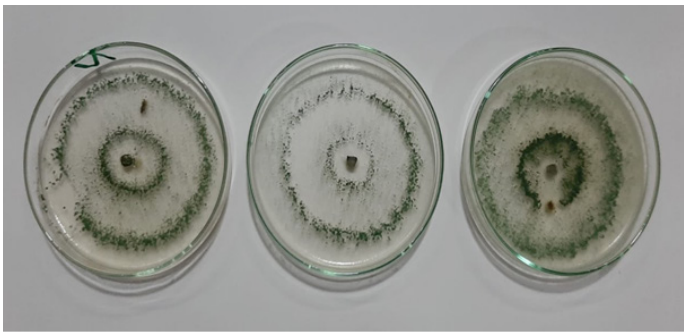

Fig. 4. No observed effect of nano-silicon on *Trichoderma* under used doses. That means nano-Si did not cause any harmful impacts on these useful microorganisms in the media

Consent for publication

All authors declare their consent for publication.

Funding

This research received no external funding.

Author contribution

The manuscript was edited and revised by all authors.

Conflicts of Interest

The author declares no conflict of interest.

Acknowledgments

The authors thank the staff members of Physiology and Breeding of Horticultural Crops Laboratory, Dept. of Horticulture, Faculty of Agriculture, Kafrelsheikh University, Kafr El-Sheikh, Egypt for conducting the most parameters as well as they helped in completing this work.

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