J. of Agricultural Chemistry and Biotechnology, Mansoura Univ., Vol. 14 (2):13 - 17, 2023

Journal of Agricultural Chemistry and Biotechnology

Journal homepage & Available online at: www.jacb.journals.ekb.eg

Mini Review: Silicate Bacteria and Plant Diseases

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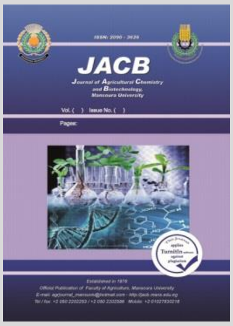

ABSTRACT

Silicate bacteria were identified for fertility management and in this review as biological control in soil. The main source of silica in soil are the silicate minerals. However, monosilicic acid is the only soluble form of silicon for plant absorbation. This acid (monosilicic acid) can be produced by several ways such as rock-weathering mostly of these ways depends on microbial activities namely silicate solubilizing bacteria (SSB). The present work discussed silicate solubilizing bacteria as a very important factor in this scale and commonly used in plant diseases. The very important role of silicate bacteria is converting insoluble forms of silicates minerals to soluble ones. Furthermore, silicate bacteria can also solubilize other beneficial element for plant such as potassium. Potassium element enhances plant defense mechanisms against phytopathogens and hence increase soil fertility to develope growth of plants. Silicate bacteria enhance resistance against several soil borne fungi with supplementation of silicon which inhibits many plant-pathogen systems and protects plants against pathogens. By producing bacterial metabolites such as organic acids and the antagonistic activity of this bacteria against the pathogens the silicate bacteria can protect the plants. Thus, the silicate-mediated can affect bioavailability of silicon by decreasing doses of pesticide use, sustainable agriculture and developed health of plant.

Keywords: silicate bacteria, biocontrol, plant diseases

INTRODUCTION

Biological control

In several scales of biology, most plant pathology and entamology the terms " biological control " and its abbreviated synonym " biocontrol " have been used. In plant pathology, this term means the use of microbial antagonists to inhibit diseases as well as the use of host-specific pathogens to control weed populations. In both scales, the microoorganism that prevents the pest or pathogen is referred to as the biological control agent (BCA). Because the term biological control can added to a spectrum of knowlege, it is important for the term when it is applied to the review of any particular work (Pal and McSpadden, 2006). The main biocontrol agents that have been reported for controlling phytopathogens are fungi and bacteria and particularly soilborne fungi (Whipps and McQuilken,1993). One from the most important factors of biological control to inhibite plant pathogenic fungi is the silicate solubilizing bacteria. Silicon fertilizer are the most efficient factor for environment and protect plant from diseases (Meena *et al.*, 2014).

Silicate bacteria

Avaycan *et al*. (1981) found that silicate bacteria belong to different species of bacteria such as *Bacillus circulans* and *Pseudomonas* sp. Figure (1) reprsentes colonies of silicate bacteria on the selective agar medium. Colonies were mucous having the shape of tears which appear in the incident light as shining structure like glass (Afify, 1982).

Also, Afify (1982) found that there were differences in the distribution of silicate bacteria and bacterial strains that capable of actively solubilizing orthoclase. These bacteria were found to be sporulated rod shaped (Figure 2) and identified as *Bacillus circulans.*

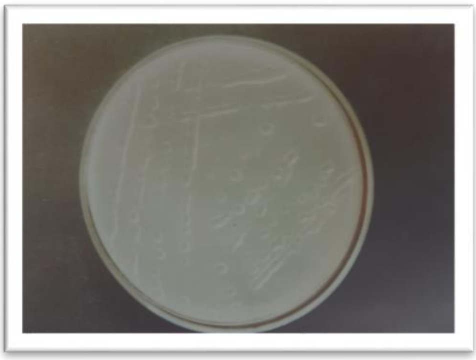

Figure 1. Shape and appearance of colonies of silicate bacteria on Aleksandrov's agar medium (Afify, 1982).

Figure 2. Morphological characteristics of the sporulated rod shaped strain of *Bacillus circulans* under light microscope (Afify,1982).

Balabel (1997) observed many purified isolates of silicate bacteria, among these bacteria long sporulated rods and short non sporulated rod shaped. These isolates were

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DOI: 10.21608/jacb.2023.185124.1043

found to be belonging to *Bacillus circulans, Entrobacter sakazakki* and *Pseudomonas mendosina* (Figures 3 and 4).

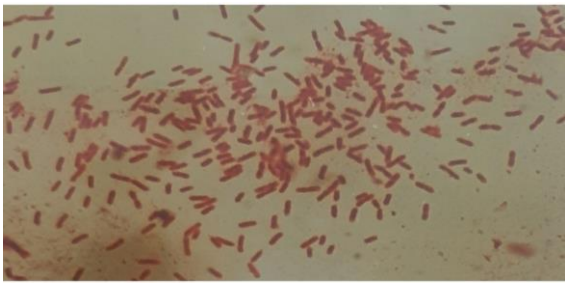

Figure 3. Morphological characteristics of the long sporulated rod shaped strains of *Bacillus circulans* under light microscope (Balabel, 1997).

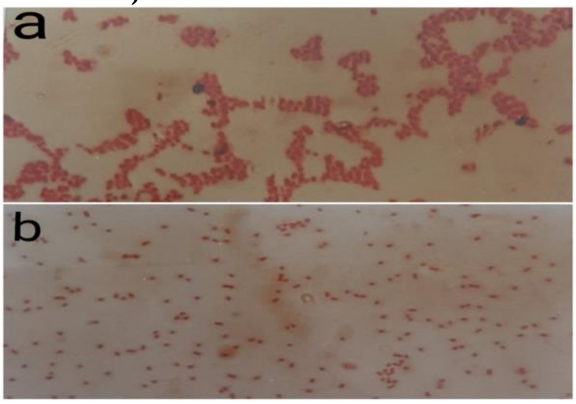

Figure 4. Morphological characteristics of the two short non-sporulated rod shaped strains (a) *Enterobacret sakazakii* and (b) *Pseudomonas mendocina* under light microscope (Balabel, 1997).

Afify and Bayoumy (2001) isolated and identified two bacterial strains capable of actively solubilizing biotite and muscovite. One strain was short rods, non sporulated identified as *Proteus mirabilis* and other strain was long sporulated rods in chains, encapsulated on selective medium identified as *Bacillus circulans*.

Approximately the phylum Proteobacteria and Firmicutes were contain many genera of silicate bacteria have been described originally placed. Some genera of these silicate bacteria are *Bacillus, Psudomonas, Proteus, Enterobacter* etc. (Raturi *et al.,* 2021). Moreover, now most of silicate bacteria belong to several genera have been characterised and identified (Figure 5).

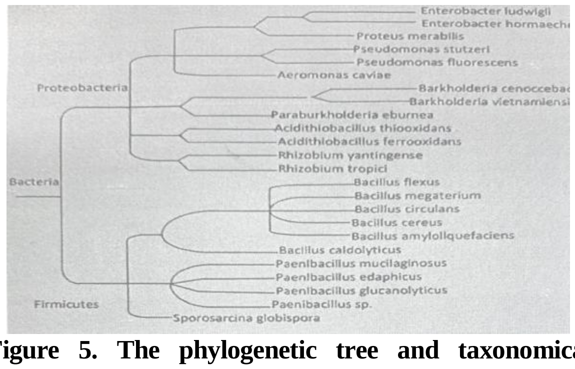

Figure 5. The phylogenetic tree and taxonomical distribution of silicate bacteria. (https://phylot.biobyte.de/).(Raturi *et al.,* 2021).

In this study, biocontrol will be narrowly focued as highlight in silicate bacteria. Finally, several genera of bacteria are essential part for weathering silicate minerals namely biological agents. These bacteria referred as " silicate bacteria" have the ability to decompose aluminosilicate minerals to increase silicate elements (potassium, silicon and aluminum) in an available forms for plant nutrition (Afify, 2022).

Silicate bacteria and phytopathognic fungi

At the first time, Krivchenko (1958) reported that the application of bacterial silicate inoculants as means of increasing soil fertility and resistability to certain plant pathogens might released potassium and silicon of Luxury plant consumption.

The bacterial silicate has claimed to develope beneficial effect on plant growth by the increase of absorbed potassium in the plants. Soil inoculation with silicate bacteria had a main factor on the increase of potassium and silicon which up-take by plant (Zahra *et al*., 1984). Plant can be diseases a direct effect in the destruction of natural resources in agriculture espcially, aggressive phytopathogenic fungi which cause most losses crops. In the last few years introduced big changes in farming, with determental effects on crops of economic importance through the distribution of several soilborne fungi, such as *Pythium, Phytophthora, Botrytis, Rhizoctonia* and *Fusarium* (Chet *et al*., 1997). Enhancement of resident antagonists is risk-free when the bacterial silicate that antagonize plant pathogens (biocontrol agents) (Monte, 2001).

Silicon and biocontrol mechanisms of silicate bacteria

Maxwell *et al.* (1972) noted that polymerized silicic acids in the rice plant are strongly bound to cellulose forming a silicocellulose membrane and can only be separated after the cellulose is dissolved. Silicon forms crystals of plant opal (Figure 6).

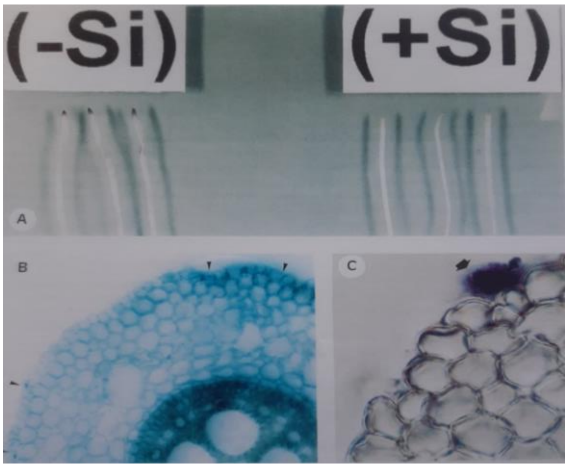

Figure 6. (A) Hematoxylin staining of root tips of plant pretreated with (+Si) or without (-Si) 1mM Si for 72h and then exposed for 24 h to solutions without Si containing 50 µM Al. (B,C) Hematoxylin staining of free hand sections of mature root zones of Si . (B) and +Si (C) plants exposed to 50 µM Al (Maxwell *et al.,* 1972).

Forbes and Waston (1992) reported that while silicon described as a microelement for plant nutrition, it is an important factor to enhance protection of plants against diseases. Application of silicon to the soil as nutrient solution resulted in decrease in plant diseases , resistance of insects ,reduction of toxicities of minerals and improvement in plant growth and yield (Belanger *et al*., 1995). Silicon can acts as a bioprotectant against fungal attack (Datnoff *et al*., 1997). The silicon combines when applied to the soil has been reported to increase the resistance of the plants. This resistance related to the silicon content of the plant, particularly the leaves (Mark *et al.,* 1997).The silicon can stimulates accumulation of polymerized phenolic compounds, through the metabolic processes in plants which produce H_2O_2 that causes damage to the cell oxidation function (Noctor *et al*., 2000). To decrease the harmful of fungal diseases in a number of pathosystems it has known by silicon (Si). That is reported by deposition of amorphous silica in the leaf apoplast which prevent penetration the pathogenic fungi (Fawe *et al.*, 2001).

To increase resistance and prevent the penetration of pathogenic fungi Carver *et al.* (1987) and Francosis *et al.* (2005) stated that the silicon (Si) developes the growth and yield of several crops and reduces the incidence effect of phytopathogenic fungi by strengthening the cell walls in leaves and especially the outer membrane of epidermal cells.

The improve resist plants require silica against both stress biotic or abiotic (Ma *et al*., 2004). Silicon can protect host tissues from penetration of pathogen (Liang *et al.,* 2005). Simonsson *et al* ., 2007 reported that potassium plays an efficient role in metabolic processes and protect plants from disease , because potassium can improve growth of plants.

The amass silicon not essential for growth the crops but improve induction of systemic resistance (ISR) to antagonise fungal diseases (Vijayapriya and Muthukkaruppan, 2010). Silicon could act as physical barrier against pathogen penetration and as inducer for defence response in plant (Shen *et al*., 2010).

Bacterial silicate can play an important role in solubilizing insoluble forms of silicates minerals hence increase soil fertility and plant defense mechanisms against plant pathogens (Vasanthi *et al*., 2012). Potassium is very important element because its deficincy appears to symptoms like chlorosis and leaf fall, weakly roots, reduction in nutrient uptake.

Furthermore, the silicate solubilizing bacteria introduce a main system of biocontrol agents of plant pathogenic fungi by the availability of some elements such as: silicon and potassium in soil. Fertilization by silicon is very important for improving resistance against plant diseases and environment (Meena *et al.,* 2014). The ways for silicate solubilizing bacteria can antagonize fungal pathogens as : hydrolytic enzymes, siderphores, HCN and antibiotics (Naureen *et al*., 2009 ; Hassan *et al.*, 2010 and Naureen *et al*., 2015 b). Naureen *et al.* (2015 a) observed the the inhibition zone by antagonistic activites of selected silicate bacteria against plant pathogenic fungi. These inhibition zones are recorded in Table (1).

These bacteria can directly and indirectly combat phyto-pathogenic fungi, directly by antagonizing growth of fungal pathogens while indirectly by increasing silicon in soil which in turn induces disease resistance in plants by acting as a modulator of host resistance to pathogen by mecanically impedes penetration of fungi (Bowen *et al*., 1992 and Sahebi *et al*., 2015).

Table 1. Inhibition of some pathogenic fungi by selected bacterial isolates (Naureen *et al.*, 2015 a).

Bacterial Silicates No.	Inhibition zone (mm) after 7 days against fungi			
	Magnaporthae grisae	*Rhizoctonia solani*	*Altarnaria alternata*	*Fusarium moniliformae*
1	20	18	16	17
2	34	29	23	21
3	39	33	25	31
4	18	16	17	17
5	29	18	19	13
6	18	18	14	10
7	20	18	16	17
8	18	18	14	17
9	14	14	8	15
10	14	14	8	15

Chandrakala *et al.* (2019) concluded that silicon is a beneficial nutrient for plant growth promotion and plant protection. Also, silicon improves resistance against many diseases (Liang *et al* ., 2005; Hawerroth *et al*., 2019). Silicon also prevent parasitic anglosperms , insects , and nematodes to penetrate plants (Keeping *et al*., 2009 ; Silva *et al*., 2010; Lukacova *et al.,* 2019).

Gaurav *et al* . (2021) stated that silicate solubilizing bacteria can benefit the plants by producing the antagonsitic activity against the pathogens. Recantly, Afify and Ashour (2022) showed high antagonistic activity against two plant pathogenic fungi *in vitro* by using daul cultural technique. Also in this study, these bacteria produced the antagonistic metabolites such as: siderophores, hydrogen cyanide, ammonia and hydrolytic enzymes.

Examples of biocontrol plant diseases by silicate bacteria

Miyake and Tokahashi (1983) reported that the silicate minerals suppressed Fusarium wilt of cucumber**.** Cherif and Belanger, 1992 evaluate that decreased mortaility, root decay and yield losses attributed to infection with *Pythium ultimum,* as well as increased root dry weight and number of fruits on cucumber by the potassium silicate. Also, Cherif and Belanger, 1992 found that soluble silicon resulted in an increase in the activities of enzymes oxidases.

Agarie (1993) reported that silicon prevent destruction of chlorophyII. Solube silicon exhibited a potential impact of improve resistance to fungal diseases. Belanger *et al*. (1995) and Quanzhi and Erming (1998) found that silicon can cause improve photosynthesis**.** An application of silicic acid to plants can control diseases and also decrease the amount of fungicides that increased into the environment (Ma *et al.,* 2004). Inhibition effect of silicon against pathogens in the soil has been reported since the 1920_s (Kanto *et al*., 2006). The same authors controlled the powdery mildew of strawberry and suppressed the disease more efficiency as a protective than as a control to diminish initial incidence liquid potassium silicate as soil drench. Also strawberry leaf hardness for the control and silicate – treated leaves was harder than control leaves they measured . Rodrigues *et al.* (2010) suggested that to reduce the intensity of angular leaf spot on beans potassium silicate sprays should be used. Jayawardana *et al*. (2014) studied the root and foliar application of potassium silicate on the growth of plant, quality of furit and development anthracnose disease in fruits and proved that the disease occurrence was reduced after two days treatments compared to the control.

Gaurav *et al.* (2021) reported that the silicate-mediated can affect bioavailability of silicon and reducing pesticide use, sustainable agriculture and developed plant growth. Afify and Ashour (2022) recommended that silicate bacteria should be used for the developmant of bio-fungicides against fungal pathogens.

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بكتيريا السليكات و أمراض النبات

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الملخص

من المخصبات الحيويه بكتيريا السيلكات وفى هذه الدراسه المرجعيه من عوامل المقاومه الحيويه فى التربه والمصدر الرئيسى للسليكات فى التربه هى المعادن السليكاتيه حيث أن الصوره الذائبه والميسره لإمتصاص النبات حمض السيكليك الأحادى. ويتكون هذا الحمض بطرق عديده مثل تجوية هذه المعادن ولكن أهم طرق تكوينه النشاط الميكروبى بواسطة البكتيريا المذيبه للسليكات. وهنا فى هذه الدراسه والتى تحتوى مواضيعها على التأثير الواضح للبكتيريا المذيبه للسليكات وتطبيقاتها فى أمراض النبات حيث نجد أن بكتيريا السليكات لها دور كبير فى التربه فى تأثيرها على صور السليكات غير الذائبه بالإضافه إلى دورها فى تيسير عنصر البوتاسيوم وبالتالى تعمل على تحسين خصوبة التربه مما يؤدى إلى وقاية النباتات ونجد أن دور هذه البكتيريا فى مقاومة أمراض النباتات أنها تنتج أحماض عضويه ومواد أخرى مضاده توقف نشاط المسببات المرضيه . ولهذا فإن بكتيريا السليكات تزيد تيسيير عنصر السليكون حيويا (ميكروبيا) وعناصرأخرى وبالتالى تقلل من إستخدام المبيدات الكيميائيه مما يؤدى إلى إنتاج نباتات صحيه وتحسين الزراعه .