Adv. Hort. Sci., 2018 32(2): 289-295 DOI: 10.13128/ahs-21873

short note

AHS
Advances in Horticultural Science

Growth of potato genotypes under different silicon concentrations

A.O.S. Dorneles [1 (*)], **A.S. Pereira** [2], **G. Possebom** [2], **V.M. Sasso** [2], **L.V. Rossato** [2], **L.A. Tabaldi** [2]

[1] *Federal Pelotas University - UFPel, Botany Department, Capão do Leão, RS, Brazil.*

[2] *Federal Santa Maria University - UFSM, Biology Department, Santa Maria, RS, Brazil.*

Key words: beneficial element, hydroponic, *Solanum tuberosum,* stress.

(*) **Corresponding author:**
athos_odin@hotmail.com

Citation:
DORNELES A.O.S., PEREIRA A.S., POSSEBOM G., SASSO V.M., ROSSATO L.V., TABALDI L.A., 2018 - *Growth of potato genotypes under different silicon concentrations.* - Adv. Hort. Sci., 32(2): 289-295

Data Availability Statement:
All relevant data are within the paper and its Supporting Information files.

Competing Interests:
The authors declare no competing interests.

Received for publication 10 October 2017
Accepted for publication 12 January 2018

Abstract: The aim of this work was to verify the beneficial potential of Silicon on the growth of potato genotypes in order to select potato genotypes that best respond to Si application. Four potato genotypes were used: SMIJ319-7, Dakota Rose, SMIF212-3 and SMINIA793101, grown in hydroponic system. The plants were transferred to nutrient solutions with four Si concentrations: 0; 0.5; 2.5; and 5.0 mM as $NaSiO_3$. After seven days of exposure to treatments, leaf area, leaf number, shoot length, and fresh and dry weight of roots, stem and leaves were determined. The application of 0.5 mM Si promoted an increase in growth parameters of plants used in this work, mainly in leaf area, leaf number, and leaf and stem dry weight. However, the application of higher concentrations of Si (2.5 mM) promoted reduction in the growth parameters, mainly in leaf area. It was also possible to observe a genotypic variation with respect to Si, SMIJ319-7 and SMIF212-3 genotypes being the most responsive to Si. Therefore, the concentration of 0.5 mM Si is considered optimal for potentiating the growth of potato plants, and SMIJ319-7 and SMIF212-3 genotypes are the most responsive to Si.

1. Introduction

Potato (*Solanum tuberosum* L.) is one of the most produced food crops in the world, after rice, wheat and maize (Faostat, 2014), and because of its popularity it is known as "The king of vegetables" (Roy *et al.,* 2017). The current potato production in Brazil exceeds three million tons per year, with a planted area of more than 130 thousand hectares (Faostat, 2014).

Many variables affect the performance of potato plants. Among the ones manageable by man, nutritional management is one of the most important (Westermann and Davis, 1992). In southern Brazil, potato is cultivated predominantly in acid soils, poor in calcium, magnesium and with high aluminum (Al) and manganese contents. Accordingly, there is evidence that silicon (Si) interacts with aqueous Al, thereby reducing its bioavailability (and thus toxicity) and at the same time increasing the bioavailability of the essential element phosphorus (Dietzel, 2002; Farooq and Dietz, 2015).

After oxygen, Si is the second most abundant element in lithosphere and soil, representing about 28% of Earth's crust (Gunes *et al.,* 2007). Silicon is considered an essential element only for some species belonging to Poaceae and Cyperaceae families (Liang *et al.,* 2005), but the beneficial effects of this element in growth, development, yield and resistance to disease have been observed in a wide variety of plant species (Ma, 2004). Yet it is not possible to demonstrate its essentiality to all higher plants due to the fact that there is no direct evidence that it participates of a molecule or of a constituent or metabolite essential for plants (Epstein, 1999).

The beneficial effects of Si to plants are most evident under conditions of stress (Ma and Yamaji, 2008). Published data suggest that Si increases tolerance to drought (Gong *et al.,* 2005), toxic metals (Gu *et al.,* 2011), UV-B radiation (Li *et al.,* 2004), salt stress (Liang *et al.,* 2003) and resistance of plants to pests and pathogens (Gao *et al.,* 2011). Silicon also alleviates mineral stress, such as manganese (Mn) and aluminum (Al) toxicity, and P deficiency (Iwasaki *et al.,* 2002).

A considerable amount of Si is found in various food products, like grains/cereals and their products (e.g. breakfast cereals, bread, beer), fruit and certain vegetables (bananas, currants, beans, lentils), and all natural waters (Bissé *et al.,* 2005). According to Nielsen (2009), a high consumption of Si may be beneficial, facilitating the absorption or the use of some minerals, including magnesium and copper, which are essential for growth and bone maintenance, cardiovascular health and wound healing.

There is no current information available on beneficial effects of Si on the growth of potato genotypes. Taking into account that about 40% of the world's arable soils have acid pH and toxic concentrations of Al (Ramanujan, 2014), including the soils in Rio Grande do Sul, and that potatoes are grown in a large area in this state, it is important to analyze the effect of Si on potato plant growth. The objective of this study was to analyze the effect of different Si concentrations on the growth parameters of potato genotypes, seeking to select potato genotypes more responsive to Si and the optimal Si concentration.

2. Materials and Methods

The tests were carried out at the Laboratory of Plant Biotechnology and in greenhouses belonging to the Department of Biology at the Federal University of Santa Maria. Four potato (*Solanum tuberosum* L.) genotypes were used: SMIJ319-7, Dakota Rose, SMIF212-3 and SMINIA793101.

Microtubers of four potato genotypes obtained from the Genetics Program and Improvement of Potato, UFSM, Santa Maria, RS, were propagated in plastic cups of 300 mL, using sand as substrate, and irrigated daily with nutrient solution. After about three weeks, 40 uniform plants of each genotype (shoot length of 5 cm) were chosen, the roots were washed in running water to remove the substrate and plants were transferred to hydroponic system consisting of a vessel with capacity of one liter. The plants were exposed to complete nutrient solution for three days for acclimatization. The nutrient solution was as follows (in µM): 6090.5 N; 974.3 Mg; 4986.76 Cl; 2679.2 K; 2436.2 Ca; 359.9 S; 243.592 P; 0.47 Cu; 2.00 Mn; Zn 1.99; Ni 0.17; B 24.97; 0.52 Mo; 47.99 Fe ($FeSO_4$/Na EDTA). After this acclimatization period, the plants were cultured for seven days in a new nutrient solution (pH 4.5±0.1) exposed to four different concentrations of silicon (Si): 0; 0.5; 2.5; and 5.0 mM, as $NaSiO_3$. This pH was used to ensure greater availability of Si, and to prevent its interaction with cations in the solution. The treatments were arranged in a randomized design, with 10 replicates per treatment and one plant for repetition. The nutrient solution with Si treatments was replaced every 48 hours and pH was adjusted daily.

Seven days after the start of exposure to treatments, the plants were collected to determine leaf area (with leaf area integrator AM 300, ADC BioScientific Ltd.), leaf number, shoot lenght (with scale graduated in millimeters) and dry weight of leaves, stem and roots.

For the statistical analysis, the data was checked for normal distribution of errors by the Anderson-Darling test and homogeneity of variances by the Bartlett test for all experiment variables. When these assumptions were met, it was proceeded to variance analysis and Scott-Knott test for treatments at 5% error probability, using Sisvar application (Ferreira, 2008).

3. Results and Discussion

For SMIJ319-7 and SMINIA793101 genotypes, the concentration of 0.5 mM silicon (Si) promoted an increase in leaf area compared with control (without Si) (Fig. 1A). This result is consistent with studies of other species showing the Si ability, when applied at low levels (Barcelo *et al.,* 1993), to stimulate growth and development of plants, particularly under abiotic and biotic stress (Epstein, 1999; Ma, 2004; Liang et *al.,* 2007; Dorneles *et al.,* 2017).

The increase in leaf area promoted by Si can result in greater interception of solar radiation, and consequently greater accumulation of biomass in these plants. For SMIF212-3 and Dakota Rose genotypes, there were different responses in leaf area among treatments (Fig. 1A), indicating that there is a genotypic variation in relation to Si effects on potato plants. The concentrations of 2.5 and 5.0 mM Si promoted a reduction in leaf area in Dakota Rose genotype compared with control, suggesting that in this genotype, this parameter is more sensitive to high Si concentrations. Besides, the concentration of 2.5 mM of Si also promoted leaf area reduction for SMIJ319-7 and SMINIA793101 genotypes. Silicon is able to interact with essential ions to plants, such as Mg, Zn and Fe (Liang *et al.,* 2005; da Cunha *et al.,* 2008; Naeem *et al.,* 2014), thus the excess of Si may lead to the immobilization of these elements in the apoplast of these plants.

For the SMIJ319-7, SMIF212-3 and SMINIA793101 genotypes, 0.5 mM Si promoted an increase in the leaf number compared to the control (Fig. 1B), while for the Dakota Rose genotype there was no significant difference among treatments. The literature reports that Si plays a favorable role in growth by improving the acquisition of mineral nutrients (Lee *et al.,* 2010), possibly due to a kinetic relationship with some nutrient absorption, thereby causing an increase in biomass production. Thus, due to the pH level used in this work, the effect of Si should take place in the plant, which may lead to a better distribution of nutrients throughout the plant.

The presence of Si in the growth medium significantly influenced on shoot length of potato genotypes (Fig. 1C), where there was significant difference between Si concentrations and control (without Si). For the Dakota Rose genotype, in all Si concentrations, it was observed decreased shoot length compared to control (Fig. 1C). Besides, for the SMINIA793101 genotype, there was a reduction in plant height at 2.5 mM Si. On the other hand, Si concentration of 0.5 mM promoted increase in plant height for SMIJ319-7 and SMIF212-3 genotypes, thus this concentration can be optimal for the growth of potato plants. These data suggest that Si has significant and beneficial effect on this parameter for all genotypes, except for Dakota Rose, which did not obtain a positive response to Si application.

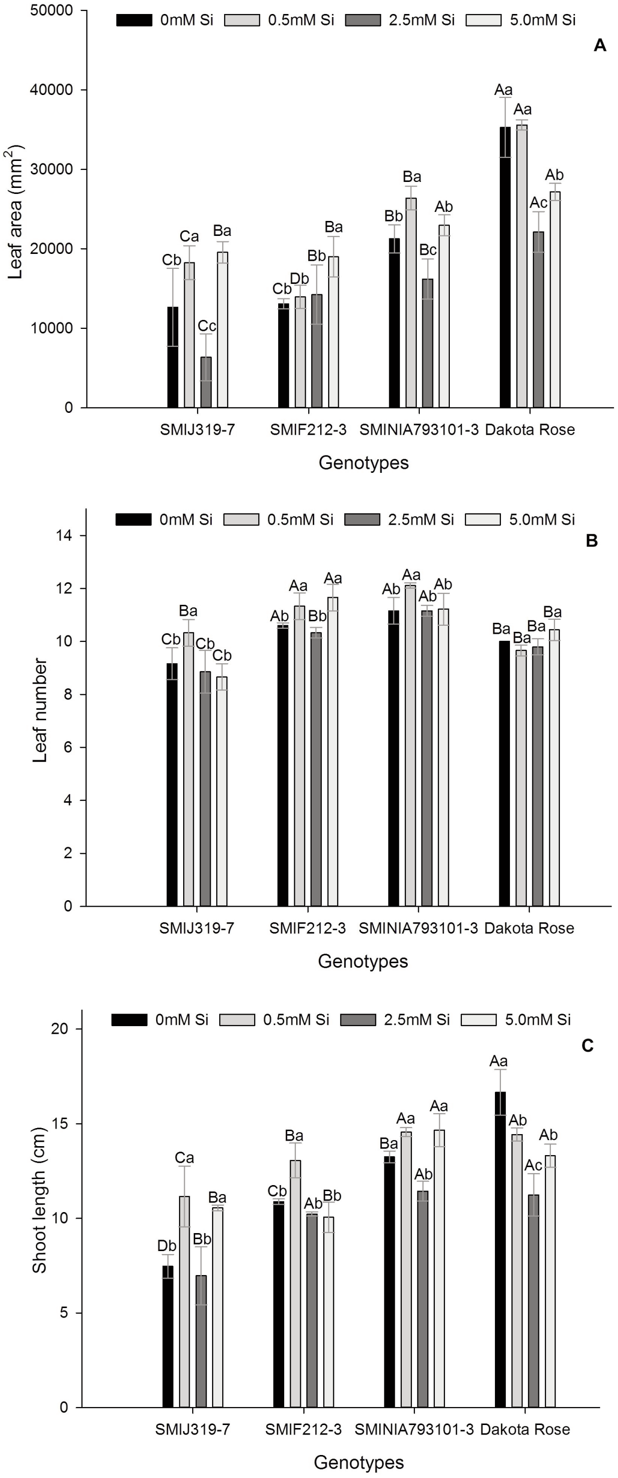

Fig. 1 - Leaf area (A), leaf number (B) and shoot length (C) of potato genotypes exposed to different silicon concentrations in growth medium. Different lowercase letters indicate significant differences between treatments in the same genotype. Different capital letters indicate significant differences between genotypes in the same treatment.

Silicon at 0.5 and 5.0 mM caused a significant increase in yield of leaf dry weight only for SMIJ319-7 and SMIF212-3 genotypes compared to the control (without Si) (Fig. 2A). In SMIJ319-7 plants, increased biomass accumulation induced by Si coincided with increase in leaf area, which may have promoted a greater area of interception of sunlight. For SMIF212-3 genotypes, the increase of leaf dry weight may be explained by Si accumulation in the leaves, because this genotype did not present increase in leaf area. The increase in biomass of potato plants observed in our study might be due to a higher rate of photosynthesis, chlorophyll content and increased activity of enzyme ribulose 1,5-bisphosphate carboxylase caused by Si (Lee *et al.,* 2010). On the other hand, 2.5 mM Si promoted a reduction on leaf dry weight for SMINIA793101 and Dakota Rose genotypes. This reduction in leaf dry weight accumulation caused by the application of 2.5 mM Si in the genotypes SMINIA793101 and Dakota Rose may be due to this concentration not being sufficient for the activation of possible Si transporters, which may be more active in higher concentrations. Some non-accumulating Si species like *Cucumbita moschata* Duch. and *Solanum tuberosum* present differences in the expression of Si transporters with increased application of this element (Mitani *et al.,* 2011 a, b; Vulavala *et al.,* 2016).

For the SMIJ319-7 genotype, Si concentrations (0.5 and 5.0 mM) promoted an increase in the production of stem dry weight compared to control (Fig. 2B). The concentration of 0.5 mM Si also promoted an increase in stem dry weight production for SMINIA793101 genotype. Silicon deposited in tissues can improve light trapping features for maintaining more upright the leaf blade (Epstein, 1999), resulting in increase of plant biomass. This deposition of Si in tissues may have contributed to the increase of biomass due to possible formation of a barrier to transpiracional flow that could lead to higher efficiency use of water (Lux *et al.,* 2002; Shi *et al.,* 2005). On other hand, for the SMIF212-3 and Dakota Rose genotypes, there was a negative effect of Si on the production of stem dry weight.

For the root dry weight, there was significant difference between the Si concentrations in all genotypes, where the presence of 0.5 mM Si promoted an increase in root dry weight compared to control (Fig. 2C). On the other hand, higher concentrations of Si (2.5 and 5.0 mM) generally promoted a reduction in root dry weight compared to control. This indicates that lower Si concentration (0.5 mM) is beneficial for this parameter, but higher concentrations may be detrimental to root dry weight. In addition, this accumulation of root dry weight is in agreement with low stem dry weight for the Dakota Rose genotype, indi-

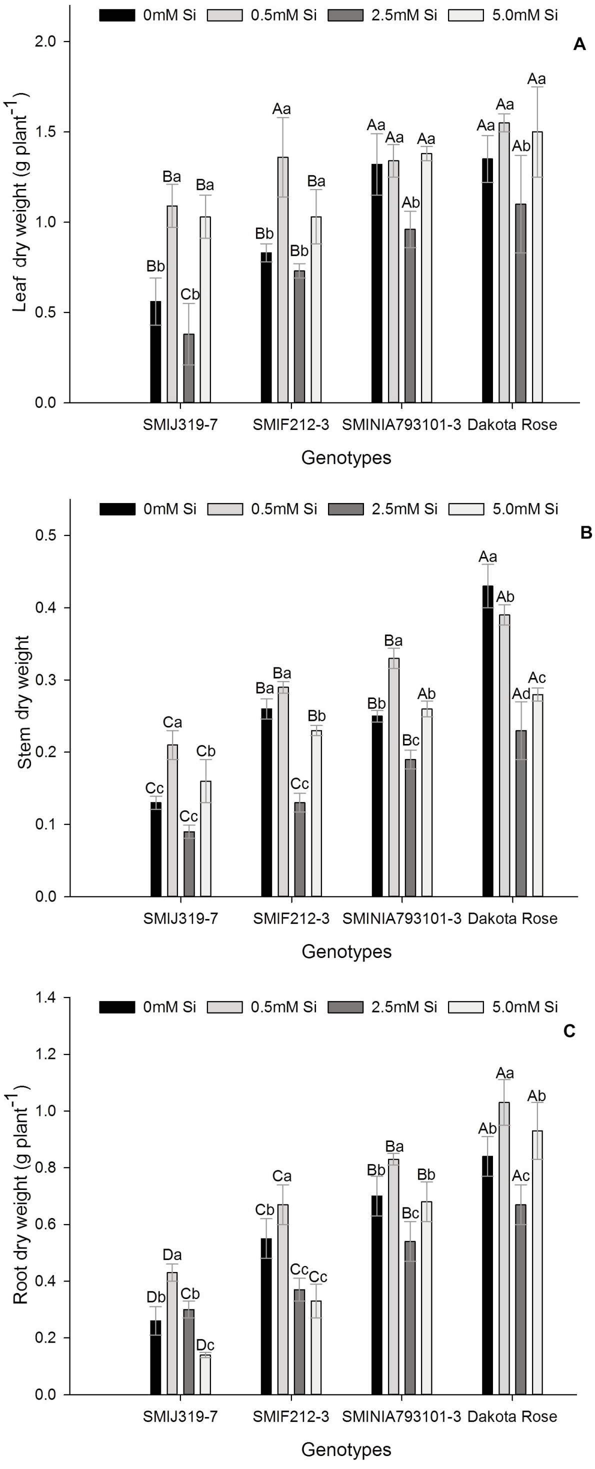

Fig. 2 - Leaf dry weight (A), stem dry weight (B) and root dry weight (C) of potato genotypes exposed to different silicon concentrations in growth medium. Different lowercase letters indicate significant differences between treatments in the same genotype. Different capital letters indicate significant differences between genotypes in the same treatment.

cating a Si effect on the mobilization of resources and their accumulation in roots.

The behavior pattern of the genotypes in relation to Si was similar. However, the Dakota Rose genotype has a higher root dry weight accumulation when compared to the other genotypes. Nevertheless, it is possible to observe that the effect of Si concentrations on root dry weight accumulation for the Dakota Rose and SMINIA793101 genotypes follow a similar behavior pattern. The same may be observed when comparing the behavior pattern of the SMIJ319-7 and SMIF212-3 genotypes, which are also similar. These data show that genotypes SMIJ319-7 and SMIF212-3 are more responsive to Si compared to genotypes Dakota Rose and SMINIA793101. These behavior patterns may be observed on all parameters of this work, and may be explained by differences on expression of putative Si-transporter, which may differ among genotypes and Si concentrations (Mitani *et al.,* 2011 a, b; Vulavala *et al.,* 2016).

At high concentrations (2.5 and 5.0 mM), silicon led to reduction of some growth parameters evaluated in the genotypes used in this study. This response may be due to Si effects on immobilizing and complex cations in plants apoplast (Shi *et al.,* 2005; Moussa, 2006; Farooq and Dietz, 2015). Some of these cations may be nutrients such as zinc, magnesium and manganese, thereby the reduced absorption by the plant may lead to nutritional stress in the long term.

In addition, the silicon deposited in leaves may reduce the transpiration avoiding water loss by plants (Hodson *et al.,* 2005; Farooq and Dietz, 2015). However, the excess of silicon on leaf surface may possibly reduce transpiration so that it reduces photosynthetic processes that depend on gas exchange and constant water flow.

Most research currently focus on Si potential in abiotic stresses mitigation (Dorneles *et al.,* 2016; Pavlovic *et al.,* 2016; Ashfaque *et al.,* 2017). However, studies demonstrating Si effects at high concentrations are scarce and show that high concentrations of this element may reduce the productive and qualitative potential of plants (Marodin *et al.,* 2016; De Souza Ferraz *et al.,* 2017). In addition, some plant species are specialized in absorbing, transporting and accumulating Si in their tissues due to the presence of specific transporters (Farooq *et al.,* 2015; Sanglard *et al.,* 2016). Such carriers may also be present in other species (Mitani *et al.,* 2011 b). Vulavala *et al.* (2016) demonstrated that the genotype 'Winston' of *Solanum tuberosum* has mechanisms of transport responsive to Si. It is possible that the differences in the responses of the genotypes of this study are due to differences in the expression of these transporters. This reinforces the importance of the present study, which provides data for future recommendations for Si application in potato plants.

4. Conclusions

The concentration of 0.5 mM of silicon may be considered optimal, since it induced an increase in growth parameters in potato plants, especially in leaf area, leaf number and biomass of leaves and stems. Furthermore, the most responsive genotypes to Si were SMIJ319-7 and SMIF212-3, possibly due to molecular characteristics such as presence of Si transporters. However, high Si concentrations may lead to unfavorable responses in some potato genotypes.

References

ASHFAQUE F., INAM A., IQBAL S., SAHAY S., 2017 - *Response of silicon on metal accumulation, photosynthetic inhibition and oxidative stress in chromium-induced mustard (*Brassica juncea *L.)*. - South African Journal of Botany, 111: 153-160.

BARCELO J., GUEVARA P., POSCHENRIEDER C., 1993 - *Silicon amelioration of aluminium toxicity in teosinte (*Zea mays *L. ssp.* mexicana*)*. - Plant and Soil, 154(2): 249-255.

BISSÉ E., EPTING T., BEIL A., LINDINGER G., LANG H., WIELAND H., 2005 - *Reference values for serum silicon in adults.* - Analytical Biochemistry, 337(1): 130-135.

DA CUNHA K.P.V., DO NASCIMENTO C.W.A., DA SILVA A.J., 2008 - *Silicon alleviates the toxicity of cadmium and zinc for maize (*Zea mays *L.) grown on a contaminated soil.* - J. Plant Nutr. Soil Sci., 171: 849-853.

DE SOUZA FERRAZ R.L., DE ANDRADE BARBOSA M., MAGALHÃES I.D., DE MELO A.S., DO SOCORRO ROCHA M., DA SILVA COSTA P., 2017 - *Atributos qualitativos de sementes de algodoeiro hidrocondicionadas em soluções de silício.* - Científica, 45(1): 85-94.

DIETZEL M., 2002 - *Interaction of polysilicic and monosilicic acid with mineral surfaces,* pp. 207–235. - In: STOBER I., and K. BUCHER (eds.) *Water-rock interaction.* - Kluwer Academic Publishers, Dordrecht, the Netherlands, pp. 1736.

DORNELES A.O.S., PEREIRA A.S., ROSSATO L.V., POSSEBOM G., SASSO V.M., BERNARDY K., TABALDI L.A., 2016 - *Silicon reduces aluminum content in tissues and ameliorates its toxic effects on potato plant growth.* - Ciência Rural, 46(3): 506-512.

DORNELES K.R., DALLAGNOL L.J., PAZDIORA P.C., RODRIGUES F.A., DEUNER S., 2017 - *Silicon potentiates biochemical defense responses of wheat against tan spot*. - Physiol. Molec. Plant Path., 97: 69-78.

EPSTEIN E., 1999 - *Silicon.* - Annual Rev. Plant Physiol. Plant Molec. Biol., 50: 641-644.

FAOSTAT, 2014 - *Statistical Database*. - Food and Agricultural Organization of United Nations, Rome, Italy.

FAROOQ M.A. DIETZ K.J., 2015 - *Silicon as versatile player in plant and human biology: overlooked and poorly understood.* - Frontiers in Plant Science, 6(994): 1-14.

FAROOQ M.A., SAQIB Z.A., AKHTAR J., BAKHAT H.F., PASALA R.K., DIETZ K.J., 2015 - *Protective role of silicon (Si) against combined stress of salinity and boron (B) toxicity by improving antioxidant enzymes activity in rice*. - Silicon, 1-5.

FERREIRA D.F., 2008 - *SISVAR: um programa para análises estatísticas e ensino de estatística.* - Revista Symposium, 6(2): 36-41.

GAO D., CAI K., CHEN J., LUO S., ZENG R., YANG J., ZHU X., 2011 - *Silicon enhances photochemical efficiency and adjusts mineral nutrient absorption in* Magnaporthe oryzae *infected rice plants.* - Acta Physiologiae Plantarum, 33(3): 675-682.

GONG H., ZHU X., CHEN K., WANG S., ZHANG C., 2005 - *Silicon alleviates oxidative damage of wheat plants in pots under drought.* - Plant Science, 169(2): 313-321.

GU H.H., QIU H., TIAN T., ZHAN S.S., CHANEY R.L., WANG S.Z., QIU R.L., 2011 - *Mitigation effects of silicon rich amendments on heavy metal accumulation in rice (*Oryza sativa *L.) planted on multi-metal contaminated acidic soil.* - Chemosphere, 83(9): 1234-1240.

GUNES A., INAL A., BAGCI E.G., PILBEAM D.J., 2007 - *Silicon-mediated changes of some physiological and enzymatic parameters symptomatic for oxidative stress in spinach and tomato grown in sodic-B toxic soil.* - Plant and Soil, 290(1-2): 103-114.

HODSON M.J., WHITE P.J., MEAD A., BROADLEY M.R., 2005 - *Phylogenetic variation in the silicon composition of plants*. - Annals of Botany, 96(6): 1027-1046.

IWASAKI K., MAIER P., FECHT M., HORST W.J., 2002 - *Effects of silicon supply on apoplastic manganese concentrations in leaves and their relation to manganese tolerance in cowpea (*Vigna unguiculata *[L.] Walp.)*. - Plant and Soil, 238(2): 281-288.

LEE S.K., SOHN E.Y., HAMAYUN M., YOON J.Y., LEE I.J., 2010 - *Effect of silicon on growth and salinity stress of soybean plant grown under hydroponic system.* - Agroforestry Systems, 80(3): 333-340.

LI W.B., SHI X.H., WANG H., ZHANG F.S., 2004 - *Effects of silicon on rice leaves resistance to ultraviolet-B.* - Acta Botanica Sinica-English Edition, 46(6): 691-697.

LIANG Y., CHEN Q.I.N., LIU Q., ZHANG W., DING R., 2003 - *Exogenous silicon (Si) increases antioxidant enzyme activity and reduces lipid peroxidation in roots of salt-stressed barley (*Hordeum vulgare *L.)*. - J. Plant Physiol., 160(10): 1157-1164.

LIANG Y., SUN W., ZHU Y.G., CHRISTIE P., 2007 - *Mechanisms of silicon mediated alleviation of abiotic stress in higher plants: a review.* - Environ. Pollution, 147: 422-428.

LIANG Y., WONG J.W.C., WEI L., 2005 - *Silicon-mediated enhancement of cadmium tolerance in maize (*Zea mays *L.) grown in cadmium contaminated soil.* - Chemosphere, 58: 475-483.

LUX A., LUXOVA M., HATTORI T., INANAGA S., SUGIMOTO Y., 2002 - *Silification in sorghum (*Sorghum bicolor*) cultivars with different drought tolerance.* **-** Physiologia Plantarum, 115: 87-92.

MA J.F., 2004 - *Role of silicon in enhancing the resistance of plants to biotic and abiotic stresses.* - Jap. Soc. Soil Sci. Plant Nut., 50: 11-18.

MA J.F., YAMAJI N., 2008 - *Functions and transport of silicon in plants.* - Cellular and Molecular Life Sciences, 65(6): 3049-3057.

MARODIN J.C., RESENDE J.T., MORALES R.G., FARIA M.V., TREVISAM A.R., FIGUEIREDO A.S., DIAS D.M., 2016 - *Tomato post-harvest durability and physicochemical quality depending on silicon sources and doses.* - Horticultura Brasileira, 34(3): 361-366.

MITANI N., YAMAJI N., AGO Y., IWASAKI K., MA J. F., 2011 a - *Isolation and functional characterization of an influx silicon transporter in two pumpkin cultivars contrasting in silicon accumulation*. - The Plant Journal, 66(2): 231-240.

MITANI N., YAMAJI N., MA J.F., 2011 b - *Silicon efflux transporters isolated from two pumpkin cultivars contrasting in Si uptake.* - Plant Signaling & Behavior, 6(7): 991-994.

MOUSSA H.R., 2006 - *Influence of exogenous application of silicon on physiological response of salt stressed maize (*Zea mays *L.)*. - Int. J. Agric. Biol.*,* 8: 293-297.

NAEEM A., GHAFOOR A., FAROOQ M., 2014 - *Suppression of cadmium concentration in wheat grains by silicon is related to its application rate and cadmium accumulating abilities of cultivars*. - J. Sci. Food Agric., 95: 2467-2472.

NIELSEN F.H., 2009 - *Micronutrients in parenteral nutrition: boron, silicon, and fluoride.* - Gastroenterology, 137: 55-60.

PAVLOVIC J., SAMARDZIC J., KOSTIC L., LAURSEN K. H., NATIC M., TIMOTIJEVIC G., NIKOLIC M., 2016 - *Silicon enhances leaf remobilization of iron in cucumber under limited iron conditions.* - Annals of Botany, 118(2): 271-280.

RAMANUJAN K., 2014 - *Aluminum tolerance fix could open arable land.* - Cornell Chronicle, Cornell University, USA.

ROY T.S., CHAKRABORTY R., PARVEZ M.N., BISWAS S., CHAKRABORTY S., 2017 - *Development of sustainable gross national income from potato export in Bangladesh - A perspective review.* - Universal Journal of Agricultural Research, 5(1): 46-51.

SANGLARD L.M.V.P., DETMANN K.C., MARTINS S.C., TEIX-

EIRA R.A., PEREIRA L.F., SANGLARD, M. L., DAMATTA F.M., 2016 - *The role of silicon in metabolic acclimation of rice plants challenged with arsenic.* - Environmental and Experimental Botany, 123, 22-36.

SHI X., ZHANG C., WANG H., ZHANG F., 2005 - *Effect of Si on the distribution of Cd in rice seedlings.* - Plant and Soil, 272(1): 53-60.

VULAVALA V.K., ELBAUM R., YERMIYAHU U., FOGELMAN E., KUMAR A., GINZBERG I., 2016 - *Silicon fertilization of potato: expression of putative transporters and tuber skin quality.* - Planta, 243(1), 217-229.

WESTERMANN D.T., DAVIS J.R., 1992 - *Potato nutritional management changes and challenges into the next century.* - American Potato Journal, 69:753-767.