Journal of Research in Biological Sciences, 01 (2014) 01-03
p- ISSN: 2356-573X / e-ISSN: 2356-5748

www.knowledgejournals.com

Review article

Silicon Biomineralisation in Plants: A Tool to Adapt Global Climate Change

Sheikh Abdul Shakoor [a,*]

[a]*Plant Systematics and Biodiversity Laboratory, Department of Botanical and Environmental Sciences, Guru Nanak Dev University, Amritsar (Punjab) INDIA-143005*
** Corresponding author. E-mail address: shakoorshiekh9@gmail.com (Sheikh Abdul Shakoor)*

Article history:
Received 31 March 2014; Accepted 17 April 2014;
Available online 9 May 2014.

Abstract

Biomineralization is the process by which living organisms influence the precipitation of mineral materials. It appears that the capacity for biomineralization has been an evolutionarily widespread and an enduring trait, because it conferred strong and obvious selective advantage to organisms that possessed it. Biomineralization is a fundamental life process by which plants gain structure and mass, virtually without tissue maintenance cost, drawing on the chemistry of the environment to find strategies for maintenance and defense. Silicified plants have been reported to be more successful in extreme environments as compared to those which do not silicify their structures. The present review is an attempt to give the brief account of role of silicon biomineralisation in climate change.

Keywords: phytoliths, plants, silica.

1. Silicon Bioneralisation-A useful Tool?

Changes in long term environmental conditions that can be collectively coined climate change are known to have had enormous impacts on plant diversity[1]. The Earth has experienced a constantly changing climate in the time since plants first evolved. In comparison to the present day, this history has seen Earth as cooler, warmer, drier and wetter, and CO_2 (carbon dioxide) concentrations have been both higher and lower[5]. In order to flourish under these changing environmental conditions, nature has evolved plants with characteristics that have boosted their fitness. One such unique characteristic is that several plant groups (algae (diatoms), certain bryophytes, pteridophytes and angiosperms particularly monocots) (Iriarte, 2003) absorb silicon in the form of monosilicic acid (H_4SiO_4) from the soil and impregnate it as silicon dioxide (SiO_2) within and between cells and tissues of vegetative and reproductive structures as amorphous bodies known as phytoliths or silica bodies (Shakoor and Mudassir, 2014).

These phytoliths are particularly abundant in the epidermis and cell wall of the plants (Fig. 1A, 1b) (Metcalf, 1960; Shakoor et al., 2014). It appears that the capacity for silicon biomineralization (silicification) has been an evolutionarily widespread and a tool, because it conferred strong and obvious selective advantages to plants that possessed it. Last half century has witnessed significant global climate changes due to urbanization and industrialization. Changing climatic variables include increasing CO_2 concentrations, increasing global temperatures, altered precipitation patterns, and changes in the pattern of ‘extreme’ weather events such as cyclones, fires or storms besides climate change also evolves disease causing agents.

Last few decades have figured an ever increasing rise in CO_2 concentration in the atmosphere leading to global warming and hence rise in temperature. Phytoliths have been found to act as CO_2 sinks (Parr and Sullivan, 2005). During their deposition and polymerization within the plant body, occlusion of carbon also takes place within the phytoliths (Fig. 1-C1 & C2). Besides carbon and silicon others elements are also present in small amounts as well (Table 1).

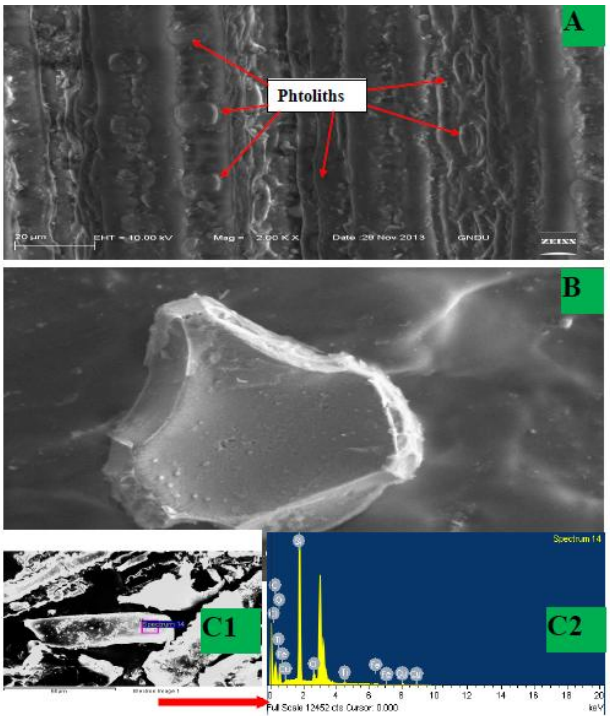

Fig. 1. Scanning Electron Micrographs and Energy Dispersive X-ray (EDX) Spectra: (A)

SEM showing different phytoliths of leaf surface of Desmostachya bipinnata (L.) Stapf (B) SEM of Isolated Phytolith from Leaf of Oryza sativa L; (C1 and C2) SEM-EDX spectra of phytoliths isolated from leaves of Henrardia persica (Boiss.) C.E. Hubb. showing the phytolith occluded carbon besides other elements.

Table 1. Elemental Compostion of phytoliths in leaf of Henardia persica (Boiss.) C.E. Hubb.

Element	Weight%	Atomic%
C K	43.26	57.77
O K	25.46	25.53
Si K	26.2	14.97
Sl K	1.91	0.86
Ti K	0.49	0.7
Fe K	0.78	0.22
Cu K	1.89	0.48
Total	100	

Some of the major agricultural crops like barley, maize, rice, sorghum, sugarcane and wheat are known to be prolific producers of phytolith and Phytolith occluded carbon (PhytOC). In India, an estimate indicates that these crops may annually contribute about 87 million tonnes (mt) of PhytOC. The rate of phytolith production and the carbon occluded in phytoliths vary among the plant community. In India, an estimate indicates that these crops may annually contribute about 87 mt of PhytOC and growing high PhytOC-yielding cultivars of these crops may additionally produce 1.05 mt of Phyt OC (Rajandiran et al., 2012). Hence these phytoliths play a significant role in ameliorating the negative impacts of increasing CO_2 concentration in atmosphere.

Drought is one of the serious consequence of global climate change restricting plant growth and crop productivity in a majority of agricultural fields of the world (Devkota and Jha, 2011; Said-Al Ahl et al., 2009). Phytoliths lend drought tolerance to plants because it maintains higher leaf water potential. This is assumed to be due to the formation of silica-cutical double layer on the epidermis and hence reducing the rate of transpiration. In addition, endodermal tissue, which plays an important role in water transport across the root, accumulates large amounts of phytoliths in mature drought-tolerant plants (Shakoor, 2014). Numerous studies demonstrate that the antioxidant defense system improves the relationship between enhanced or constitutive antioxidant enzyme activities and increased resistance to drought.

Climate change also gives birth to agents leading to infestations and diseases. These agents include bacteria, fungi and other insect-pests. Prolific silicon accumulating species are found to show resistance to all agents through diverse mechanisms. Djamin and Pathak (1967) tested several rice varieties and found that those with high silica content showed greater resistance to Asiatic stem borer (*Chilo suppressalis*) than others, probably because the silica interfered with boring and feeding of the larvae; selecting rice varieties with a high silica content was more economical than applying silicate to the soil. Hanifa et al. (1974) studied the role of silica in the resistance of rice to the leaf roller (Cnaphalocrocis medinalis), and Moore (1984) examined the relationship of silica to stem-borer infection by Oscinella species in Lolium tamulentum. Plants uptake soluble Si from the soil and deposit it in apoplast in the epidermal cell walls thus restricting penetration of fungal germ tube into the epidermis. In fact, Si improves plant resistance against fungi by improving its defensive mechanisms. Plants, which are fed Si accumulate different phenolic compounds like fungitoxic which kills the fungal hyphae that penetrate the cells.

Most serious consequence of global climate change is increased penetration of devastating and harmful Ultraviolet radiations. Phytoliths has been attributed to prevent the plants by filtering the Ultraviolet rays. In sugarcane, there is evidence that Si may play an important role in protecting leaves from ultraviolet radiation damage by filtering out harmful ultraviolet rays. Ultraviolet-B (UV-B) radiation negatively affects plant cells, causing generation of reactive oxygen species (ROS) such as superoxide anions (O_2^-), hydrogen peroxide (H_2O_2), hydroxyl radicals (OH) and singlet oxygen (O_2) (Zancan et al., 2008). Fang et al. (2011) also reported that Si increases plant tolerance to UV-B radiation. The experiment performed by Shen et al. (2010) showed that drought and UV-B radiation stresses caused intensification of Lipid peroxidation (LPO) in soybean seedlings, but Si application significantly reduced the membrane damage. The catalase (CAT) and superoxide dismutase (SOD) activities increased under the effect of UV-B radiation and significantly decreased at Si application. The UV-B light had more adverse effects on growth than drought; the data also showed that Si could alleviate seedling damage under these stress conditions.

Natural calamities like winds and typhoons may completely destroy the plants. It has been found that phytolith production in plant structures may help to maintain their structural rigidity (Shakoor and Bhat, 2014). In a number of crop plants like rice, wheat, barley etc. phytolith production has been found to increase the rigidity of stems and linear leaves, and hence provide lodging resistance to these crops.

References

Devkota, A., P.K. Jha, 2011. Influence of water stress on growth and yield of Centella asiatica. Int. Agrophys. 25: 211-214.

Djamin, A., M. Pathak, 1967. Role of silica in resistance to the Asiatic rice borer, Chilo suppressalis (Walker), in rice varieties. J. Econ. Entomol. 60: 347-351.

Fang, Ch.-X., Q-S. Wang, Y. Yu, L.-K Huang, WuX-Ch, W-X Lin, 2011. Silicon and its uptaking gene Lsi1 in regulation of rice UV-B tolerance. Acta. Agron. Sin. 37 (06): 1005-1011.

Hanifa, A.M., T.R. Subramaniam, B.W.X. Ponnaiya, 1974. Role of silica in resistance to the leaf roller, Cnaphalocrocis medinalis Guenee, in rice. Indian J. Exp. Biol. 12: 463-465.

Iriarte, J. 2003. Assessing the feasibility of identifying maize through the analysis of crossshaped size and three-dimensional morphology of phytoliths in the grasslands of southeastern South America. Journal of Archaeological Sciences 30: 1085–1,094.

Metcalfe, C.R. 1960. Anatomy of the monocotyledons: I. Gramineae. Oxford Univ. Press, London. 731.

Moore, D. 1984.The role of silica in protecting Italian ryegrass (Lolium multiflorum) from attack by dipterous stem-boring larvae (Oscinellafrit and other related species). Ann. Appl. Biol. 104: 161- 166.

Parr, J. F. and L. A., Sullivan, 2005. Soil carbon sequestration in phytoliths. Soil Biol. Biochem. 37: 117–124.

Ranjidaran, S., V.M. Coumar, S. Kundu, Ajay, M.L. Dotania and S.A. Roa, 2012. Role of phytolith occuled carbon of crop plants for enhancing soil carbon sequestration in agroecosystems. Current Science. 103 (8): 911-920

Said-Al Ahl H.A.H., E.A. Omer, N.Y. Naguib, 2009. Effect of water stress and nitrogen fertilizer on herb and essential oil of oregano. Int. Agrophys. 23: 269-275.

Shakoor, S.A. 2014.Silicon to silica bodies and their potential roles: An Overview. International Journal of Agricultural Sciences, 4 (2): 111-120.

Shakoor, S.A. and M.A. Bhat, 2014. Biomineralisation of Silicon and Calcium in Plants and Its Control: An Overview. Plant 2 (1): 6-13.

Shakoor, S.A and M.A. Bhat, 2014. Morphological diversity of phytolith types in some chloridoid grasses of Punjab. Int. J. Bot. Res. 4(1): 1-10

Shakoor, S.A., A.S. Soodan, and Kumar, K. 2014. Morphological diversity and frequency of phytolih types in giant reed Arundo donax (L.). W. App. Sci. J. 29 (7): 926-932

Shen, X., Y. Zhou, L. Duan, Z. Li, A.E. Eneji, J. Li, 2010. Silicon effects on photosynthesis and antioxidant parameters of soybean seedlings under drought and ultraviolet-B radiation. J. Plant Physiol. 167: 1248-1252.

Zancan, S., I. Suglia., N. La Rocca, R. Ghisi, 2008. Effects of UV-B radiation on antioxidant parameters of iron-deficient barley plants. Environ. Exp. Bot. 63: 71-79.