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Surprising benefits of silicon in plants and human beings

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Abstract

Silicon is the second most abundant element on Earth and the third most abundant trace element in human body. It is present in water, plant and animal sources. Silicon is known as a beautifying mineral and there are many health benefits associated with it. It is a macro element involved in the responses of plants to a variety of abiotic stresses. The culture medium composition, particularly the mineral nutrients, greatly impacts the growth as well as the morphogenesis of in vitro plant cultures. Silicon not only helps strengthen connective tissues and bones but is also useful in skin, nail, and hair care. They also play a vital role in the prevention of atherosclerosis, insomnia, tuberculosis, and aluminum toxicity. Silicon and silicic acid may decrease the bioavailability of aluminum by blocking the uptake of the latter by the gastrointestinal tract and impeding its reabsorption in the kidneys. Silicon has also been suggested to be involved in mammalian hormonal control, and protect people from heart diseases, anticancer, anti- atherosclerotic, and anti-diabetic effects.

Keywords: Silicon; Plant growth; Abiotic stress; Human disease

1. Introduction

Trace elements are a critical component that influences the functions of living organisms. Despite the fact that silicon is the second most abundant element in the biosphere after oxygen, its impact on metabolic processes is only partially understood due to its low bioavailability in humans[1]. While a daily dose of silicon of 20-30 mg for an adult, which corresponds to 0.28-0.43 mg kg^{-1}b.w. per day for a man weighing 70kg, the daily recommended intake (DRI) has yet to be determined[2]. In the human body, silicon is the third most plentiful trace element[3,4]. It can be found in hair[5], nails[6], cornfield epidermis and the epicuticle of hair in concentrations of 1–10 parts per million (ppm)[7,8]. It is found in food in the form of silicon dioxide (SiO_2), free ortho silicic acid (H_4SiO_4), silicic acids bound to particular nutrients and in the form of silicate. Despite the fact that silicon is a vital micronutrient mineral, it has received insufficient attention in our view. Since silicon is abundant in nature and in humans, it is expected to play a significant role in human and animal health[9]. Silicon can be found in the water, as well as in plants and animals. On the skin, silicon is thought to be essential for collagen synthesis and hydroxylation enzyme activation, which enhances skin strength and elasticity. Orthosilicic acid (OSA) stimulates fibroblasts to secrete collagen type at physiological concentrations, according to research. In the case of hair, it's assumed that a higher silicon content in the fibre contributes to less hair loss and more brightness. Since silicon is the most abundant mineral in nails, it has an effect on them. For these reasons, there is increasing interest in scientific studies that look into the effectiveness and safety of using silicon-containing dietary supplements to raise serum levels of this ingredient and thus strengthen the skin and its annexes[10]. Following Justus von Liebig's discovery of the function of certain elements in plant growth and development in the 19th century, we learned about the importance of mineral nutrition in agriculture[11]. Along with nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulphur (S), magnesium (Mg), and sodium, he found Si to be an important element. Silicon is one of the most important

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trace elements for human health[12] and it also plays an important role in plant health, particularly in reducing environmental stresses. Drought and salinity are the two most common stress causes and research has focused on understanding the impact of Si on abiotic and biotic stress mitigation in recent years[13-15]. It has also been described as a plant defence inducer and an insecticide resistance inhibitor, making it a good candidate for pest control in the field[16]. A definitive function of Si in the alleviation of individual mineral nutrition deficiencies has also been demonstrated among abiotic stresses[17-19]. When all tissues are good, they contain a lot of silicon, but as we get older, the amount of silicon in them decreases, and the tissues start to degrade. Silicon deficiency has also been found in clinical conditions such as atherosclerosis and neoplastic diseases[2]. It is a non-essential element for plant production and growth[20]. Plants grow normally without it, but in some cases, such as with the silicifier horsetail and rice, the lack of Si causes increased susceptibility to fungal infection[21,22]. Silicon is primarily deposited in active bone growth sites in the human body. They play an important role in bone calcification and accelerates the rate of bone mineralization, according to numerous studies. Deficiency in silicon causes deformations or delays in the development of bones, as well as problems with joint cartilage and connective tissue[23]. In the gastrointestinal tract, food silicates are hydrolyzed into readily available orthosilicic acid[2]. Although it has been suggested that silicon compounds from food in the presence of hydrochloric acid and other gastric acids in the stomach are broken down into orthosilicic acid, which easily diffuses through mucous membranes into the blood circulation system, the exact site where silicic acid is absorbed from the gastrointestinal canal has not been determined[2]. Silicosis is a lung disease caused by prolonged inhalation of silica-containing mineral dust. It is characterised by progressive fibrosis and chronic shortness of breath[24].

2. Benefits of Silicon in Plants

2.1. Benefit of Silicon in Plant Growth

Silicon has a significant impact on the production of plant roots, allowing for improved root resistance and faster growth in dry soils. Si application has been shown to improve plant growth, biomass, and photosynthetic pigments in a variety of plant species[25,26]. Under salt tension, Egyptian clover (Trifolium alexandrinum L.) obtained Si in the form of diatomite, which increased fresh and dry weight as well as total photosynthetic pigments. In a dose-dependent manner, silicon application increased cucumber plant height, fresh and dry weights, and chlorophyll content under salinity stress[25]. The application of Si to purslane (Portulaca oleracea L.) plants under salt stress improved root growth (volume, area, diameter, total and main length, and root dry weight) and shoot biomass. Furthermore, under salt tension, Si treatment increased seed weight and yield of bean plants (Phaseolus vulgaris L.)[27]. Application of Si in sand culture improved root morphological traits, total root length, surface area, total volume, and average diameter of salt-stressed tomato[28]. Many studies have found that Si has similar effects on salt-stressed wheat growth, biomass and photosynthetic pigments under various growth conditions. Rice[29], maize[30], tomato[31], sorghum[32], canola[33] and Spartina densiflora[34] have all shown beneficial effects of Si under salt stress on plant growth, biomass, and photosynthetic pigments.

2.2. Benefit of Silicon in Alleviation of Abiotic Stress

The beneficial role of Si in alleviation of abiotic stress is well established, little is known of the relevance of Si nutrition under micro and macro elements deficiency and its underlying mechanisms are poorly understood[13]. Abiotic stress is one of the most serious limitations to crop cultivation around the world. Abiotic stresses have become more frequent and difficult as a result of climate change and unpredictable weather. Most abiotic stresses, such as salinity, drought, thermal, and heavy metal stress, cause plants to develop reactive oxygen species[35]. Detailed root studies will help to explain the role of Si in metal accumulation at non-toxic concentrations, as well as the possibility of metal being transported to the shoot or not. In addition, the effects of Si on the corresponding metal molecules (such as citrate) involved in long-distance transport in plants must be considered[36]. By depositing silica in rice and increasing the thickness of the culm wall and the size of the vascular bundle[37], Si may increase the resistance of rice to lodging. The formation of hydroxyl aluminium silicate by Si is thought to contribute to Al detoxification in plants. Si may also prevent lodging in rice and wheat plants by neutralising the negative effects of increased N supply on stalk stability and lodging susceptibility[38]. According to one study, higher exudation of Al chelating catechin and quercetin, as well as malic acid, in Si-treated maize plants increased maize resistance to Al toxicity[39]. Numerous research using containers, hydroponics, and field tests have shown the beneficial effects of Si on plants. Silicon promotes upright growth (stronger and thicker roots, shorter and shorter internodes), prevents lodging, promotes favorable leaf exposure to light, offers resistance to bacterial and fungal diseases, and reduces certain abiotic stress such as temperatures, salinity, heavy metal, and aluminum toxicity[25,26].

3. Benefit of Silicon in Human Beings

3.1. Benefit of Silicon in Skin, Nail and Hair

Silicon has been recognized as one of the most essential trace elements in human metabolism. It is beneficial for skin, nail, and hair care. The content of silicon in human skin is 49.5 μg g–1 of tissue, in hair 42.0 μg g–1 of tissue and in nails 26.12 μg g–1 of tissue. It is an important element for the synthesis of collagen which leads to improving skin strength and elasticity[2]. This mineral promotes solid, healthy hair growth. Hairs that have higher silicon levels show more brightness and a lower rate of hair loss. Alopecia (hair loss) is caused by a refined diet that is deficient in nutrients, especially silicon[40]. Higher levels of silicon also protect nails against infections, and since silicon is one of the predominant minerals in the composition of nails, soft brittle nails could be a sign of silicon deficiency.

3.2. Benefit of Silicon in Bone

Silicon is predominantly accumulated in active bone growth sites in the human body[2]. Silicon plays an important role in bone calcification and accelerates the rate of bone mineralization, according to numerous studies. Since silicon is the essential component that makes up the collagen matrix upon which calcium is deposited, it is truly impossible to form bone without calcium and silicon. It also increases the rate of healing of bone dislocations and fractures. Deficiency in silicon causes deformations or delays in the development of bones, as well as problems with joint cartilage and connective tissue[23]. The presence of silicon in protein complexes, which shape the tissue's structure as a cross-linking entity, is due to its high concentration in connective tissue[41]. When a person is young and healthy, all tissues contain a lot of silicon, but as they get older, the amount of silicon in them decreases, and the tissues start to degrade[2].

3.3. Benefit of Silicon in Food Production

Silica is also found naturally in some foods and it is added to many food products and supplements[42]. Silicone being a non-reactive material helps manufacturers in preventing food contamination. Additionally, silicone is used as a lubricant in certain food processing industries to prevent food products from getting affected by toxic substances in the environment[43]. It is commonly used in the form of silicon dioxide as an anti-caking agent in foods and supplements to keep ingredients from clumping up or sticking together and it's sometimes added to liquids and beverages to control foaming and thickness[42]. Silicone rubber gaskets are used in high volume food processing units such as instant foods, biscuits, fruit juices etc. Silicone gaskets can withstand extreme hot and cold temperatures and preserve the quality of the food. Food grade silicone gaskets are used for laboratories and medical applications as well. Food grade silicone is also used in liquid form to spray on food items as an effective packaging method and prevent them from contamination[43].

3.4. Benefit of Silicon in Pharmaceutical Industries

Some pharmaceuticals contain silicon. Silicon is beneficial to the cardiovascular system because it is essential for artery structural integrity, elasticity, and permeability. Silica can help in the reduction of blood fats and cholesterol[44]. Atherosclerosis, insomnia, tuberculosis, and aluminum toxicity are all prevented with this element. Silicon has been suggested as an antidote to aluminum toxicity as it reduces Al bioavailability[4,45,46]. It has required to remove harmful and toxic heavy metals from the brain[1,47,48]. Long-term exposure to particulate crystalline silica and silicates, such as quartz and man-made fibrous silicates (e.g. asbestos), causes lung scarring, which may contribute to decreased lung capacity, lung cancer, and an increased risk of tuberculosis and heart complications. These crystalline silicates are phagocytosed by macrophages, which then release cytokines that attract and activate other immune cells, including fibroblasts, which are responsible for silicosis' excessive development of collagen (fibrotic tissue).

4. Conclusion

Silicon is an abundant element on Earth and its positive effects on plants make it important in agriculture. A thorough review of available literature showed that Si could stimulate plant growth and alleviate various biotic and abiotic stresses in plants. It seems that the use of Si in agriculture will be a sustainable strategy for the alleviation of biotic and abiotic stresses in the future. In addition, the utilization of Si may result in the promotion of plant health and may play a significant role in low-input sustainable agriculture for both food and nonfood crops. Supplying silicon to plants ideally fits in with environmentally friendly strategies for sustainable crop production. In spite of a paucity of reports about the ability of silicon application to suppress bacterial and viral pathogens, economically important bacterial and viral diseases in wheat, rice, tomato, cucumber, tobacco, and melon are efficiently controlled by silicon treatments.

However much still remains to be understood on this potential biological role of silicon. Whether silicon has an essential role in man, as it has in lower animals also remains to be established. The Establishment of a biological role for this element will have important implications for nutrition as a preventative measure, or Si containing supplements as a treatment, for bone and connective tissue diseases. They also play a vital role in the prevention of atherosclerosis, insomnia, tuberculosis, and aluminum toxicity. Silicon, in the form of silicic acid, would act locally by inducing defense reactions in elicited cells and would also contribute to systemic resistance by enhancing the production of stress hormones. Silicon has also been suggested to be involved in mammalian hormonal control, protect people from heart diseases, anticancer, anti atherosclerotic, and anti diabetic effects.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

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