



Application of Silicon: A Useful Way to Mitigate Drought Stress: An Overview

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ABSTRACT

Water scarcity is now one of the major problem all over the world and it will be more challenging in nearby future. This water scarcity is going more and more threatened as the human population is increasing and food requirement is also growing along with the issues of climatic changes. Drought stress is taken as one of the major problem to food security, as it reduces the plant growth, its production and also the quality of major agricultural crops. It hinders the cell division and reduces photosynthates and reduces plant growth, crop productivity, decreases CO₂ assimilation, minimizes the leaf water potential, closes stomata and reduces chlorophyll synthesis. In addition to this, it also affects the nutrient metabolism, translocation, respiration and carbohydrate metabolism. Silicon shows a major performance in increasing the drought tolerance in plant and improves its productivity. The physiological importance of silicon includes maximum water uptake by roots, maintenance of nutrient stability, minimized transpiration and increased photosynthesis rate. The increased activity of photosynthetic enzymes, regulation of endogenous plant hormones and osmotic adjustment also occurs by silicon. So, keeping in view the importance of silicon, the present review aims to explain the important aspects of silicon on crops and how it will work in alleviating drought stress.

Keywords: Drought Stress; Silicon Fertilizers; Drought Tolerance; Crop Production.

INTRODUCTION

Plants are exposed to many biotic and abiotic stresses (Rehman et al., 2020a; & Rehman et al., 2021b), which are distressing the plant

activity such as growth and development that constantly decrease the production of crops (Kalsoom et al., 2020; & Farooq et al., 2011).

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Among all of them drought is major reducing component (Toor et al., 2020; & Adnan, 2020). Lambers et al. (2008) stated that drought stress plays a key role in reducing the crop production than other stresses. Recently water scarcity is also one of the leading problems which effects crop production (Tayyab et al., 2018). Liu et al. (2017) concluded that drought affects the different plant growth stages, translocation and relocation of cadmium have different impacts over the drought stress in peanut plants. Drought stress disturbs the procedures of cell desiccation, decreases the cell growth and division, reduces stem elongation, leaf size and root spreading. It also affects the stomatal activity, nutrients and water relations in plants (Kaushal & Wani, 2016). Rabara et al. (2015) concluded that water scarcity disturbs 64% of the worldwide land area and estimates that it will increase in future which will result in yield loss in crop plants. Agricultural organizations are trying to find ways to maximize the food production for the humans by sustainable methods to fight and increase the production to overcome the environmental stress such as drought. As observing the water scarcity scientists tried to rise the resistance in plants against drought stress. Silicon is a microelement which plays a key role in plants life cycles and it is 8th most common element presents in abundance in nature and after oxygen it is present in abundant amount in soil. Silicon application plays a vital role in improving the growth and development of plants specially in increasing the crop production under stress condition. There are many methods to increase drought resistant in the crops but application of silicon under drought stress is the best and most economical way to improve drought tolerance and reduce yield losses caused by water scarcity. Majeed et al. (2012) concluded that silicon is an important nutrient which provide numerous benefits to plant growth and development during water stress conditions. Similarly, Bockhaven et al. (2013) studied that the application of silicon is very useful in higher plants because it decreases all environmental

stresses like plant disease, drought and salinity. Keeping in view the importance of silicon, the present review aims to explain the important aspects of silicon on crops that how it will work in alleviating drought stress,

2. Hazardous Effect of Drought Stress on Crops

The crop growth and development are continuously declined by different environmental stresses which results in decreasing the crop production. Every environmental stress decreases the crop productivity, but drought stress is one of the leading factor (Lamber et al., 2008). Barnabas et al. (2008) reported that drought stress decreases the plant growth, development and biomass buildup. Decreasing rate of crop production and water content in the leaves of crop plants is because of drought which inhibits the cell division and growth, reduce leaf area, stem elongation, root spreading, rate of photosynthesis, distress the stomatal activity and also disturbs the plant nutrients and water imbalance (Li et al., 2009). The important source through which photosynthates are formed in plant is chlorophyll. The drought stress is accountable for the deprivation of chlorophyll contents which results in less photosynthates and hence reduces the crop yield (Anjum et al., 2011). McMaster & Wilhelm (2003) observed that both wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.) complete their life cycles early because of drought stress which results in decrease crop production. Sometime, the drought stress disturbs the crop in specific phases. For instance, drought stress at anthesis stage overdue flowering in quinoa (*Chenopodium quinoa* Wild.) and wheat crop (Geerts et al., 2008) and due to late flowering grain filling are not done at correct time. Similarly, Desclau, (1996) concluded that in soybean, the grain filling is accelerated at maturity phase but yield is reduced due to smaller grains. Every crop has their own mechanism to respond against drought stress. Water absence during grain filling stage is very dangerous (Vijay, 2004). According to Liu et al. (2003) drought stress at anthesis

stage increases the pod which results in decrease of soybean crop production. Inadequate nutrients uptake is a universal spectacle in crops grown up under drought stress condition. Nitrogen (N) and phosphorus (P) are the essential nutrients which is recorded less in the root and shoots of tomato grown under drought stress (Subramanian et al., 2006). Likewise, the decline in potassium and nitrogen ion uptake has been observed in cotton (*Gossypium hirsutum* L.) under water deficit (McWilliams, 2003).

3. What is Silicon?

Silicon is present in the form of silicate minerals. Epstein, (1994) demonstrated that it is such an abundant element but it is hard to verify that it is essential in high plants. Similarly, Epstein et al. (2005) documented the importance of silicon in higher plants and considered as essential element because without silicon plants show abnormality, whereas with silicon application plants grow normally. Yang et al. (2017) & Hasanuzzaman et al. (2018) studied that silicon alleviates the adverse effects of biotic and abiotic stresses like drought, heavy metal toxicity and diseases.

3.1. Role of Silicon under Abiotic Stresses

Abiotic stresses are one of the major problems all over the world and changing climate and unexpected changing weather make the abiotic stress common and severe. Allahmoradi et al. (2011) revealed that 50% of crops are mostly lost because of abiotic stresses. Nowadays, heavy metal toxicity in soil is one of the imperative problems and serious alert to human health. So, silicon fertilizer plays a key role to reduce this effect while its mechanism shows that how silicon decreases the heavy metal toxicity (Adrees et al., 2015). The biochar in which silicon are in abundant amount like (rice biochar) are also recommended to apply because they decrease the amount of soil exchangeable aluminum and stop its movement to plant body (Qian et al., 2016). Silicon fertilizer application improved heavy metal absorption in roots and subsequently, lower concentration recorded in shoot. Similarly, silicon application also

improves copper (Cu) adsorption at the outer thin layer of root surface and restrains in the central cylinder of the root epidermis and translocation are inadequate through an improved thickening of a silicon loaded endodermis (Keller et al., 2015). Additionally, the cucumber plant treated with silicon reduce molybdenum in symplast than cell wall (Rogalla et al., 2002). The different mechanisms are adopted by silicon to enhance the salt tolerance in plants. Similarly, Chen et al. (2014); Garg & Bhandari, (2015) concluded that silicon presence in the soil reduces the sodium uptake by plants and improves the potassium and sodium ratio ($K^+ : Na^+$). Gupta & Huang (2014) concluded that salt is one of the important problem and more than half of the soil is salt affected worldwide which leads to nutrient imbalance in plants and silicon application plays a major role in reducing salt stress in plants. Lie et al. (2015) stated that silicon application improves calcium (Ca) and magnesium (Mg) rate in tomato's leaves and roots under salt stress condition and high rate of potassium, phosphorus, magnesium and calcium in Egyptian clover (Abdalla, 2011). Total photosynthetic content, stomatal conductance, transpiration rate, water use size and efficiency of stomata are improved in many crops like cucumber (Amirossadat et al., 2012) and in *Vicia faba* (Kardoni et al., 2013).

3.2. Beneficial effects of Silicon on crops

Silicon plays a key role in improving the growth and yield of crops, it also shows resistant against lodging, indorses satisfactory contact of leaves to the light. Silicon application develops a mechanism in plant body from which they can fight against different diseases like bacterial and fungal. It improves the nutrient availability to plant. Kaya et al. (2006) concluded silicon application enhances the calcium (Ca) absorption in leaves and plant roots. Silicon also plays a key part in increasing the total dry matter and chlorophyll content of the crop. Mostly in common cereals high spike size during harvest, a number of grains per spike and weight of thousand grains are recorded high due to the application of silicon (Hanafy

et al., 2008; & White, 2013). Amin et al. (2016) observed that silicon gives maximum weight of cob and high number of grains per cob. Silicon has also the capability to develop resistant against chilling. Tripathi et al. (2016) & Gugala et al. (2017) explored through their experiments that Rabi season oilseed crops show resistant against cold and yield is also improved by the application of silicon. The main contributed production part of potato and sugar beet is root tuber. So, Silicon fertilizers improve the potato and sugar beet root fresh weight and maximize the yield of root which determine production of sugar beet and potato (Tripathi et al., 2016; Artyszak et al., 2016 & Kadalli et al., 2017). The absorption of silicon from soil in roots is very high in crops as compare to forest plants in natural ecosystem. Meyer, (2001); Blecker et al. (2006); Makabe et al. (2009) & Cornelis et al. (2010) studied that sugarcane takes silicon from soil 300 kg/ha year⁻¹ and rice takes 500 kg/h year⁻¹ which is very high from forest plants they take 10 to 44 kg/ha year⁻¹. Observing the importance of silicon fertilizers several developed countries has started silicon application to soil to improve the productivity and sustainable production. Epstein, (1994) concluded that silicon fertilizer plays an important role in enhancing the production of crop like barley, wheat, corn, sugarcane and vegetable i.e. cucumber, tomato and Citrus. Many researchers have concluded that silicon application shows positive response to growth, development, improved biomass, pollination and high production of the crop (Korndörfer & Lepsch, 2001). The silicon application improves the crop growth, physiological components and yield contributing parameters (Mukhtar et al., 2012). Elawad & Green (1979) revealed that because of synergistic effect of silicon, the optimum level of nitrogen is increased which results in high production of crops.

3.3. Role of Silicon in enhancing drought tolerance in plants

Drought stress is one of the serious and major threats in agriculture, having many harmful effects on plant growth, development and

metabolic activities such as water and nutrient relationship, affect photosynthesis process and nutrient absorption (Xiong et al., 2012). Silicon application improves resistant against water scarcity (Hattori et al., 2008 & Khattab et al., 2014). Hattori et al. (2005) revealed that silicon is measured as anti-transparent which enhances drought tolerance in plants by minimizing the transpiration rate and increasing water holding capacity in leaf which results in maximum CO₂ assimilation rate. Similarly, it has been proved that silicon application enhances plant growth and crop production, decreases the lodging and supports the leaves to get the maximum light and enhance plant tolerance under drought stress condition (Fawe et al., 2001). Epstein, (2005) concluded that silicon increases nutrient availability such as phosphorus and nitrogen during drought stress. Sing et al. (2016) studied the importance of silicon application and concluded that it improves the growth rate and dry matter of wheat crop during drought stress conditions. Likewise, Saud et al. (2014) & Khattab et al. (2014) stated that silicon treatment improves growth rate of roots and enhances the total adsorbing surfaces. Hattori et al. (2003) & Lux et al. (2003) concluded that silicon application enhances the cell wall extensibility of the growing area which results in increasing root growth and maximum water intake which contributes in drought resistance. However, Gholami et al. (2013) revealed that high number of tillers, maximum dry weight of leaf and high yield in rice have been recorded by silicon. Similarly, Kaya et al. (2006) concluded that silicon fertilizer enhances growth and yield of maize under water stress. Most of the literature studies show that high dry matter, maximum crop production, enhancing pollination and improved crop growth and development have been recorded from the treatment of silicon in drought (Rodrigues et al., 2004). Likewise, Ahmed et al. (2011) studied that high chlorophyll content, maximum shoot root dry weight has been observed from the application of silicon under drought stress condition in sorghum. Similarly, Shen et al. (2010) reported that

silicon application plays a major role in enhancing the dry matter content of sorghum and soybean plants in drought. Cooke et al. (2011); Ahmed et al. (2011) reported that water uptake capability and water holding capacity are enhanced from the treatment of silicon under drought stress condition. However, silicon fertilizer enhances leaf and branch erectness, decrease lodging and water loss by reducing transpiration rate and improve phosphorus availability to plant under water stress (Narayan et al., 2008). Interestingly, silicon fertilizer enhances the maize and rice chlorophyll content, dry mass, electrolyte leakage, root shoot ratios and relative water content in drought stress condition (Kaya et al., 2006; & Helal, 2013). Similarly, Ahmed et al. (2014) & Gong et al. (2003) reported that high leaf area index has been recorded in sorghum and wheat plant from the treatment of silicon in drought stress condition.

CONCLUSION

Silicon is an important constituent of the soil and plays a major role in the life cycle of plants particularly in improving the drought tolerance and its application improves the abridged growth level made by drought stress through many mechanisms such as the development of mechanical obstacles and thus, reduces the transpiration rate. It is suggested that silicon fertilizer must be applied to overcome the drought stress and improve the yield. However, the available data regarding silicon is inadequate to fully understand the importance of silicon in improving the drought resistant mechanism of plants. Therefore, in future, further studies are required to recognize the importance of silicon to enhance drought tolerance mechanisms in plant.

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