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Research Paper

Silicon Application a Useful Tool to Mitigate Drought Stress Effects in Cereals: A Mini Review

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ABSTRACT: *Drought stress is a major problem that limit agricultural production in the world. Silicon (Si), second most abundant element in the soil, is considered as a non-essential element for crop growth. However, recent literature revealed that it had beneficial effects in plants, particularly under unfavorable conditions (salt stress, drought, heavy metals…). Thus, it is classified as quasi-essential element, its absence had negative consequence in plant growth and development. Si plays an important role in improving plant response to water deficit stress. The present review focuses on the effect of Si in increasing germination, seedling growth attributes, physiological traits and plant yield and its components under drought stress.*
.***KEYWORDS:*** *Drought, Silicon, Plant performances*

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I. INTRODUCTION

Plants are often exposed to various abiotic stress during their life cycle. Drought is the most severe stress affecting plant growth, development and productivity, it occurs due to increased temperature and low rainfall [1]. Also, climate change is forecasted to increase drought disasters and to extent drought-prone areas [2]. It is the major cause of significant crop loss in the world decreasing grain yields for most main crop plants by average 50 % [3]. Water stress induced by polyethylene glycol decreased germination attributes and seedling growth traits: germination percentage, germination rate, seedling vigor index, root and shoot length and shoot and root weight of maize and sorghum seeds [4]. Increasing osmotic potential significantly decreased germination traits and coleoptile length in bread wheat [5]. In 18 rice genotypes, highest stress (20% PEG) level, decreased germination percentage from 95.8% in control to 6.6 % [6]. Drought stress decreased relative water content, chlorophyll content, spade values membrane stability index, number of tillers, spike dry matter, grains spike−1 and straw and grain production of wheat genotypes [7, 8]. In pot experiment, under stressed and non stressed conditions, water deficit stress reduced plant height, spike length, number of spikelets spike−1, relative water, and chlorophyll contents by 26 %, 9 %, 23 %, 16 %, and 11 % respectively in six bread wheat and six durum wheat [9]. Drought stress significantly affected leaf area, photosynthetic pigments, total soluble sugars shoot and root traits, water use efficiency, plant height, panicle number, grain number, 1000 grain weight, plant biomass, and harvest index in rice plants [10, 11, 12] and in maize genotypes [13].

Recently, different studies showed the positive effect of nutrients in water deficit stress alleviation in plants such as silicon application, which has gain attention by increasing plant tolerance to abiotic stress, particularly drought [14]. Therefore, the objective of this review is to examine the role of Si in mitigating drought stress effect on plant performances.

II. SILICON

In earth crust, Silicon (Si) is the second most abundant element comprising approximately 29 % (28.8 % wt) and it is in combination with other element forming oxides or silicates which are not available for plants [15, 16]. Depending on soil types, Si content range from 1 to 45 % [17]. Except for histosols (organic soil), major mineral soils are counting of sands (frequently SiO_2), these silicate are biogeochemically inert but not extremely soluble [18].

Si occurs mainly as monosilicic acid (H_4SiO_4) in soil solution which is the form absorbed by plants, concentration ranges from 0.1 to 0.6 mM at a pH level between 5.5 and 7.5. Also, Si solubility is highly dependent on soil texture, organic matter temperature, and accompanying ions [19].

III. SILICON IN PLANTS

Silicon content in plant tissues ranges from 0.1 to 10 % Si on a dry weight basis [20]. Plant Si accumulation depends on species (within the same species) and genotype [21]. Basid on biogenic solica content, plants are arranged in Si accumulators, which accumulate > 4 % Si in their tissues (Equisetales, Cyperales and Poales), intermediate which show > 1 % Si (Cucurbitales, Urticales and Commelinaceae) and excluders showing < 0.5 % Si [21]. This variability in plant Si content is linked to Si transporters in roots.

IV. SILICON AND DROUGHT STRESS

Si has been reported to improve plant response to various abiotic stress such as drought. It deposits in stomata as well, which decrease transpiration (about 30 % in rice). Also, could increase drought tolerance by improving root length [23, 24].

4.1 Beneficial Effects of Silicon on Germination and Seedling Growth Attributes

Grain germination and seedling growth are crucial stages in plant growth [25]. Seed germination and health and coleoptile length are the primary aspect sensitive to drought [26]. Thus, improving grain drought tolerance is a crucial concern to mitigate adverse effect of drought stress. Silicon treatments has been used to improve seed drought tolerance. Silicon application (15 mg/l) increased germination percentage, germination index, length of shoot and roots , seedling fresh weight and seedling vigor index by 22.37 %, 25.69 %, 21.65 %, 20.81 %, 27.80 % and 38.95 % under stressed conditions in durum wheat genotypes [27]. Under osmotic stress induced by polyethylene glycol, silicon addition improved germination rate, seedling length and vigor index by 17.45 %, 164.67 % and 143.12 % respectively using 20 mg/l of Si in 11 durum wheat varieties. Compared to control, seed germination, dry weigh per-plant and plant vigor of maize were higher under Si fortified conditions [28, 29].

4.2 Role of Silicon in Improving Physiological Plant Response to Drought Stress

Several studies have showed the positive effects of silicon application in plants physiological responses to drought stress. The addition of 1.0 mM of Si increased, leaf water potential, chlorophyll content and relative water contents and decreased proline concentration of wheat plants under water deficit stress [30, 31, 32]. In maize genotypes silicon application had positive impacts on anthesis- silking stage, stomatal density and canopy temperature [28]. Also, silicon foliar supply improved N, P, K, and Si content in white oat flag leaf [33]. Mavrič Čermelj et al. [34] reported that Si exogenous application increased photosynthetic efficiency and cell membrane integrity in maize under water deficiency conditions. Also, it enhanced relative water content and water potential of sugarance [35].

4.3 Silicon Improves Plant Yield and Its Related Traits under Drought Stress

Previous literature reported that highest yields were obtained by silicon addition. Applied during the reproductive growth stage of rice, silicon resulted in a high yield coupled with higher seed number and higher 1000-seed weight [36]. Results of Agostinho et al. [37] revealed that an improvement in biomass and tiller production by 42 % and 25 % respectively were unregistered in rice receiving Si foliar treatment. Highest grain number per panicle, grain-setting rate, 1000-grain weight and grain yield were obtained by the highest level of Si fertilizer [17]. In wheat varieties, Silica gel resulted in a high spike length, biological yield, hundred grain weight and grain yield (14.3 cm, 7.63 g pot-1, 3.97 g pot-1 and 2.46 g pot-1 respectively) [38]. Also, Si foliar application augmented K and Si concentrations, spikes number per m^2 which result in grain yield increase by 26.9 % [33]. Irrespective of the addition methods (seed priming and soil incorporation), Si influence maize growth and yield, it improved cob length, 100-kernel weight and grain yield under water-deficit stress [39].

V. CONCLUSION

Climate change and increased demand for food production are forcing natural resources to shortage. Also, drought stress is a serious threat for plant production and its performances from the germination stage to maturity. Therefore, new approaches to alleviate deficit water impacts and to improve management in agriculture are needed. This review showed that silicon application is a useful tool to battle drought stress by enhancing seed germination and seedling growth traits and increasing plant growth and yields in cereals, which are among Si accumulators crops. Thus, the use of this element can improve plant production in arid and semi-arid regions. Moreover, more researches are required to understand silicon role in drought tolerance mechanism.

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