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Silicon mediates arsenic tolerance in rice (*Oryza sativa* L.) through lowering of arsenic uptake and improved antioxidant defence system

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ABSTRACT

Arsenic (As) contamination of paddy rice in South and South-East Asia has raised much concern as rice is the subsidence diet for millions. Two contrasting rice (*Oryza sativa* L.) cultivars i.e. Triguna (As tolerant) and IET-4786 (As sensitive) were grown hydroponically to study the effect of silicon (Si) supplementation on As accumulation, growth, oxidative stress and antioxidative defence system in shoots during arsenite [As(III)] stress. Rice seedlings were exposed to three As(III) levels (0, 10 and 25 μM) and three silicic acid levels (0, 0.5 and 1 mM Si) in solution culture experiments. Addition of 1 mM Si during As(III) exposure significantly lowers shoot As accumulation in both the cultivar, but more prominently in Triguna ($P \leq 0.01$) than IET-4786 ($P \leq 0.05$). However, addition of Si during As(III) stress had no significant effect on shoot length and dry weight ($P < 0.01$) of both the cultivars, compared to their As(III) treated plants. In contrast to IET-4786 ($P \leq 0.05$), Triguna tolerated As induced oxidative stress through elevated level of cysteine, enhanced antioxidant enzymes activities and their isozymes. Upon Si supplementation lower conglomeration of oxidative stress parameters viz., superoxide and peroxide radicals, lipid peroxidation and electrolyte leakage coincides with increased antioxidants activities and enhanced level of thiols, more effectively in shoots of Triguna than IET-4786 during As(III) stress ($P \leq 0.05$). In conclusion, 1 mM Si addition, significantly ameliorates As induced oxidative stress in Triguna cultivar by lowering the As accumulation and improving antioxidant and thiolic system compared to IET-4786, implying genotypic differences with Triguna being less susceptible to stress dependent membrane lipid peroxidation.

1. Introduction

Arsenic (As) is a class one carcinogen and toxic to all forms of life. In South and South-East Asia, mining activities, use of arsenical pesticides, and irrigation with As-contaminated groundwater result in substantial As accumulation in soil (Zhao et al., 2010). The presence of As in soils or irrigation with As contaminated water may lead to its accumulation in crop plants especially rice. Recent work on rice-As demonstrated that Asian rice contains more inorganic As (As_i) then US rice and play important role for food chain contamination (Meharg et al., 2009; Zhao et al., 2010). Now it is established that consumption of rice constitutes a large proportion of the dietary intake of As_i for populations whose staple food is rice (Mondal and Polya, 2008; Meharg et al., 2009). Furthermore, rice straw is widely used as cattle feed, also containing higher levels of As than grain, thus exhibiting another route of As entry into the food chain (Panaullah et al., 2009).

Though As toxicity depends on the presence of exact As species, but generally the inorganic forms viz., arsenite [As(III)] and arsenate [As(V)] are more prevalent and toxic than the organic forms in terrestrial environments (Zhao et al., 2010). In plants, As(V) is taken up by phosphate transporters (Tripathi et al., 2007), whereas As(III) and undissociated methylated As species are transported through the nodulin 26-like intrinsic (NIP) aquaporin channels (Ma et al., 2008; Li et al., 2009a,b). Rice is particularly efficient in As accumulation compared with other cereal crops (Williams et al., 2007), because of increased availability of soil As during anaerobic flooded conditions (Xu et al., 2008) and due to sharing the highly efficient Si uptake pathway (Zhao et al., 2010).

Silicon is essential for high and sustainable production of rice (Liang et al., 2007) and the Si transporter Lsi1 (OsNIP2;1) is a major uptake pathway for As(III) in rice (Ma et al., 2008). Bogdan and Schenk (2008) observed that indigenous silicic acid inhibits As uptake in rice while Norton et al. (2010) established a positive

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