Regulation of fluoride stress response in indica rice cultivars: damage, defence and amelioration

Abstract of the thesis

Population explosion in recent decades has led to severe environmental issues. One such significant drawback of unregulated population growth is unwanted release of xenobiotics such as fluoride in the environment. Excess deposition of fluoride in the ground and surface water bodies affects plant health and development. The aim of this Doctoral Thesis was to highlight the effects of fluoride toxicity on rice varieties. Exposure to sodium fluoride led to higher accumulation of fluoride ions due to higher expression of chloride channels in 10 and 20 day-old Khitish and MTU1010, respectively that significantly hampered the growth of seedlings. Additionally, fluoride toxicity also triggered the formation of superoxide ions and H_2O_2 that caused membrane peroxidation leading to higher electrolyte leakage, formation of cytotoxic metabolites like ammonium ions, methylglyoxal and malondialdehyde along with higher LOX and NOX activity. Fluoride accumulation also led to degradation of the chlorophyll. Contrastingly, higher adaptability against fluoride stress was noted in 20 and 10 day-old Khitish and MTU1010 seedlings, respectively which was attributed to higher expression of FEX and H^+-ATPase along with efficient uptake and utilization of macroelements such as nitrogen and sulfur. Exogenous application of protective chemicals such as calcium and silicon lowered the uptake of fluoride ions by chelating them and by forming a protective barrier in the roots, respectively, that inhibited the absorption of fluoride ions. Moreover, higher endogenous level of calcium and silicon also induced the formation of osmolytes and non-enzymatic antioxidants and activity of enzymatic antioxidants that detoxified the reactive oxygen species accumulated in the tissues which in turn reduced the effects of fluoride-induced oxidative stress. Priming of seeds with calcium compounds also improved carbon metabolism in seedlings by restoring the activity of enzymes involved in tricarboxylic acid cycle along with sucrose and starch metabolism that provided sufficient energy to overcome the stressed environment. Furthermore, the role of abscisic acid (ABA) in fluoride stress was also studied since its protective role in case of other abiotic stress is widely known. Reduced ABA accumulation led to higher accumulation of gibberellic acid and melatonin in fluoride-stressed Nonabokra and Matla seedlings that promoted their tolerance level. However, higher ABA content in Jarava seedlings upregulated the expression

of chloride channels that stimulated the uptake of fluoride ions, leading to severe fluoride-mediated damage in spite of higher accumulation of polyamines and osmolytes like proline and glycine betaine via concerted action of genes like *ODC*, *ADC*, *DAO*, *PAO*, *SAMDC*, *SPDS*, *SPMS* and *PDH*. Treatment of seedlings with ABA inhibitor (Na_2WO_4) promoted fluoride tolerance in seedlings, whereas supplementation with exogenous ABA further aggravated the symptoms of fluoride toxicity. Overall, the studies undertaken in this thesis highlight the toxic effects of fluoride in rice plants and showcase the promising role of calcium and silicon in reverting back the normal growth of seedlings. Furthermore, data obtained also highlighted that fluoride tolerance is negatively regulated or is independent of ABA and ABA signaling pathway, but is rather efficiently regulated by the ABA antagonists like melatonin and gibberellic acid.

Ankur Singh

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