（第３号様式）(Form No. 3)

学 位 論 文 要 旨
Dissertation Abstract

氏名： Anisur Rahman
Name

学位論文題目：
Title of Dissertation

Calcium and Manganese-Induced Abiotic Stress Tolerance in Rice by Coordinated Action of Antioxidant Defense, Glyoxalase System and Nutrient Homeostasis

(カルシウムおよびマンガンにより誘導されるイネの非生物的ストレス耐性は抗酸化防御、グリオキサラーゼ系および栄養恒常性による協調作用に依存している)

学位論文要旨：
Dissertation Abstract

The global climate change and the complex nature of environment lead the abiotic stresses to become major constraint to crop production. Of the abiotic stresses, the toxic metal Cd is carcinogen which can easily enter in food cycle through plant accumulation. On the other hand, salt is one of the most brutal environmental factors limiting the crop productivity as most of the crop plants are sensitive to higher level of salinity. The essential plant element calcium (Ca) plays roles as second messenger molecule which mediates many aspects of cell and plant development, as well as the stress resistance response. The essential element manganese (Mn) also plays crucial role in many metabolic process that participates in the plant defense against oxidative stress. Considering the devastating effect of environmental stresses and positive role of Ca and Mn, the present studies were undertaken to investigate the regulatory role of exogenous Ca and Mn in enhancing the nutrient homeostasis, antioxidant defense and glyoxalase systems under abiotic stress (Cd and salt) in rice.

In the first study, exposure of Cd (0.25 and 0.5 mM) to hydroponically grown rice seedlings caused higher Cd accumulation, chlorosis and growth inhibition. Higher accumulation of Cd induced oxidative stress through overproduction of reactive oxygen species (ROS) and disrupting the antioxidant defense system. The level of oxidative damage increased with increasing the level of Cd stress. Cadmium treatment also increased the methylglyoxal (MG) level. However, Ca supplementation in the Cd-treated seedlings reduced Cd uptake. Exogenous Ca upregulated antioxidant defense and glyoxalase systems which reversed overproduced ROS and MG. The upregulated antioxidant defense and glyoxalase systems act co-ordinately in reducing Cd-induced toxicity.

In our second study, we observed that, salt stress (200 mM NaCl) caused growth inhibition, chlorosis and water shortage in the rice seedlings. The salt-induced stress disrupted ion homeostasis through Na^{+} influx and K^{+} efflux, and decreased other mineral nutrient uptake. Salt-induced stress caused oxidative stress in rice seedlings through lipid

peroxidation, and oveproduction of ROS and MG. However, exogenous application of 2 mM $CaCl_2$ improved ion homeostasis by inhibition of Na^+ influx and K^+ leakage. Exogenous Ca also improved ROS and MG detoxification by improving the antioxidant defense and glyoxalase systems, respectively. On the other hand, applying EGTA along with salt and Ca again negatively affected the rice seedlings as EGTA negated Ca effect. It confirms that, the positive responses in salt-stressed rice seedlings to exogenous Ca were for Ca-mediated responses.

In the third study, we found that exposure of 0.3 mM $CdCl_2$ to hydroponically grown rice seedlings caused higher accumulation of Cd. Higher accumulation of Cd caused growth inhibition, cholorosis, nutrient imbalance. Higher amounts of Cd uptake also caused oxidative stress through lipid peroxidation and overproduction of ROS and MG. Exogenous application of 0.3 mM $MnSO_4$ to Cd-treated seedlings partially recovered Cd-induced damage by reducing Cd uptake and its further translocation to the upper part of the plant. Supplemental Mn also reduced Cd-induced oxidative damage by reducing lipid peroxidation and enhancing ROS and MG detoxification through enhancing the antioxidant defense and glyoxalase systems, respectively.

In our fourth study, we noticed that, exposure of 150 mM NaCl resulted ionic toxicity and osmotic stress in rice seedlings. Ionic and osmotic stress consequently resulted in oxidative stress by overproduction of ROS and MG, respectively. The salt-induced damage increased with the increasing duration of salt stress. However, supplementation of Mn in salt-treated seedlings partially recovered growth inhibition, chlorosis by improving ionic and osmotic homeostasis. Exogenous application of Mn increased ROS detoxification by improving antioxidant defense system along with increasing phenolic and flavonoid contents. Supplemental Mn also reinforced MG detoxification by upregulating glyoxalase system. Thus, exogenous application of Mn conferred salt stress tolerance by coordinated action of ion homeostasis, antioxidant defense and glyoxalase systems in salt-affected seedlings.

The possible causes of alleviation of abiotic stress by Ca and Mn supplementation are coordinated actions of nutrient homeostasis, antioxidant defense and glyoxalase system which regulated by Ca- and Mn-mediated response. Another cause might be competitive potential of Ca and Mn with divalent toxic metal and inhibitory capacity to reduce Na^+ uptake and translocation, which also plays roles in mitigating heavy metal and salt stress by reducing their uptake.