Mechanisms of Tolerance to Zinc Deficiency in Rice

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Low Zn availability in soils reduces crop yields and Zn deficiency in human populations is one of the most widespread and pernicious health problems in developing countries. In response there are major efforts to increase the bioavailable content of Zn – and other micronutrients – in crop plants. Rice is one of the main crops being targeted because Zn deficiency is a particular problem in submerged paddy soils. Changes in soil chemistry following submergence result in Zn being immobilized in very insoluble forms, which restricts plant uptake even though total Zn contents are generally non-limiting. This may be linked to high soil pH and excess HCO_3, such as in the calcareous soils of the Indo-Gangetic plains of India and Bangladesh; but it also occurs in perennially wet, young non-calcareous soils, and in peats and coastal saline soils. Up to 50% of the global rice area is affected.

There is large variation in the rice germplasm in tolerance of Zn deficient soils and in ability to concentrate Zn in grains. Current research is using gene mapping and subsequent marker-aided selection to exploit this variation to improve rice yields on Zn deficient soils and to develop rice with high grain Zn. Related research is investigating the mechanisms behind the genotype differences. The methods used include (a) physiological studies of gene mapping populations, (b) mathematical modelling of root-soil interactions and processes in the rhizosphere, and (c) a novel technique based on fractionation of stable Zn isotopes at natural abundance to distinguish specific uptake mechanisms. These studies together have shown that three key mechanisms enhance seedling growth in Zn deficient soil: (a) maintenance of new root growth, (b) prevention of root damage by oxygen radicals linked to high HCO_3, (c) root-induced alteration of the chemistry of the rhizosphere leading to neutralization of HCO_3 and solubilisation of Zn. These mechanisms have been demonstrated for seedling-stage growth, and may also enhance Zn uptake during grain-filling stages.