Differences in Metal Accumulation Abilities among Rice Cultivars

Background

Plants showing a special ability in metal accumulation, such as hyper-accumulators and ultra-low-accumulators, are necessary for phytoremediation of contaminated soil with harmful metals like cadmium and cropping without contamination in at least in edible parts of plants (i.e. contaminant-free cropping). On the other hand, rice plants are the most common crop in Japan, and the mechanisms of some essential metal uptakes, which are highly related to harmful metal uptakes, are well analyzed at both the physiological and molecular levels. It is probable that comparisons of some metal uptake abilities between rice and the other plant species or among rice cultivars provide useful information to breed hyper-accumulators and ultra-low-accumulators.

Objectives

This study aims to clarify tolerances and accumulation abilities for copper, zinc and cadmium in some cultivars of rice, and compare the abilities with the other plant species. It also aims to clarify the cross effect of excess metal (i.e. iron, copper, zinc and cadmium) exposures on the abilities.

Principal Results

Totally, 36 families 81 genera 114 species/subspecies of herbal angiosperms commonly grown in Japan, and 12 and 7 cultivars of rice plants showing Japonica and Indica phenotypes, respectively, were provided for the experiments and gave the following results:

1. Differences in copper, zinc and cadmium tolerance and accumulation ability between rice plants and the other plant species

Tolerances and accumulation abilities for copper, zinc and cadmium were observed in each species of plants and the relative statuses were compared between rice plants and the other plant species. The rice plants commonly showed relatively higher tolerances against copper, zinc and cadmium than the other species of plants. On the other hand, every metal concentration in rice plants, which were utilized as an index of the metal accumulation ability, was limited in a middle- and narrow-ranged concentration in comparison to the other species of plants (Fig. 1).

2. Differences in copper, zinc and cadmium tolerances among rice cultivars and a speculation of the mechanisms

Each of the tolerances against copper, zinc and cadmium and correlations between two of these tolerances clearly indicated a difference between Japonica phenotype and Indica phenotype (Fig. 2). This suggested the existence of phenotype-specific mechanism for each metal tolerance.

3. Differences in divalent metal accumulation abilities among rice cultivars and a speculation of the mechanisms

The concentrations of iron, copper and cadmium in upper parts of the rice plants showing Japonica phenotype were higher than those of the rice plants showing Indica phenotype at the control condition; however, this tendency was inverted under the excess iron exposure condition (Fig. 3). This indicated the possibility that cadmium mainly shared the same mechanism with iron and copper to migrate from root to shoot. Also, it is possible that the mechanism was differently regulated in the rice plants showing Japonica phenotype and Indica phenotype.

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Future Developments

Genes related to metal transport will be isolated using the knowledge obtained by this research. Subsequently, a hypothesis that the metal tolerance and accumulation ability among rice cultivars is basically dependent on the mechanism of a specific metal accumulation and/or the transport will be certified with the isolated gene expressions and/or the functions. In addition, the genes will be utilized to breed hyper-accumulators and ultra-low-accumulators.

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Reference

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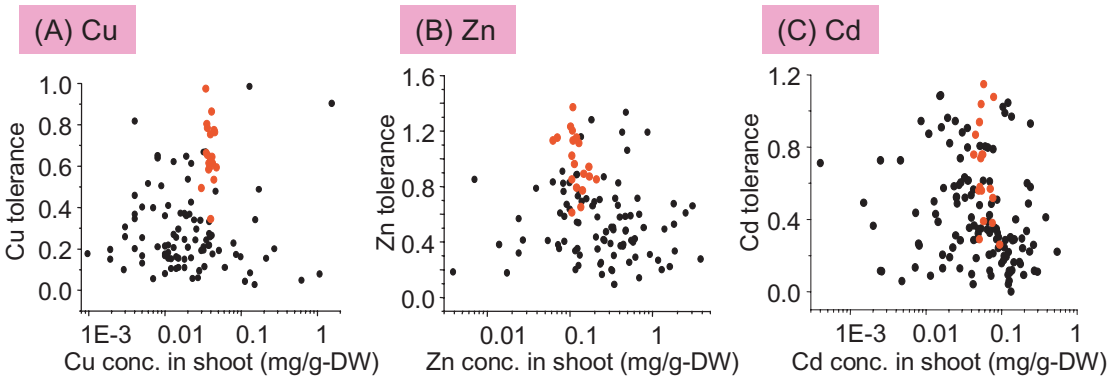


Fig.1 Relative correlations between tolerance and accumulation ability for Cu, Zn and Cd among common plant species

Correlations for Cu (A), Zn (B) and Cd (C) were indicated. Each dot shows the data for one plant species. Red dots show the data for rice plants.

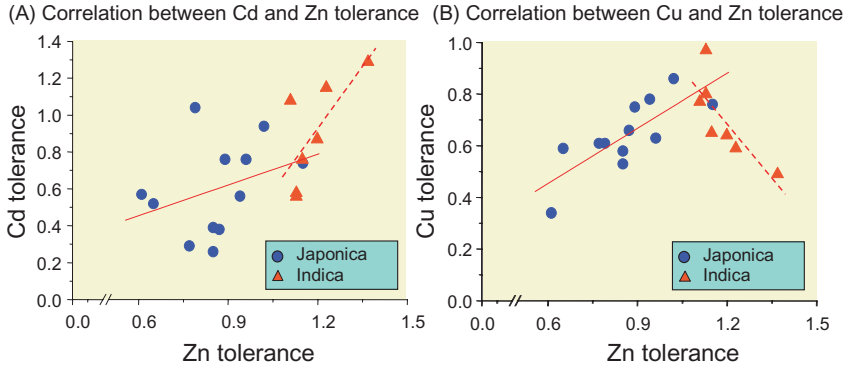
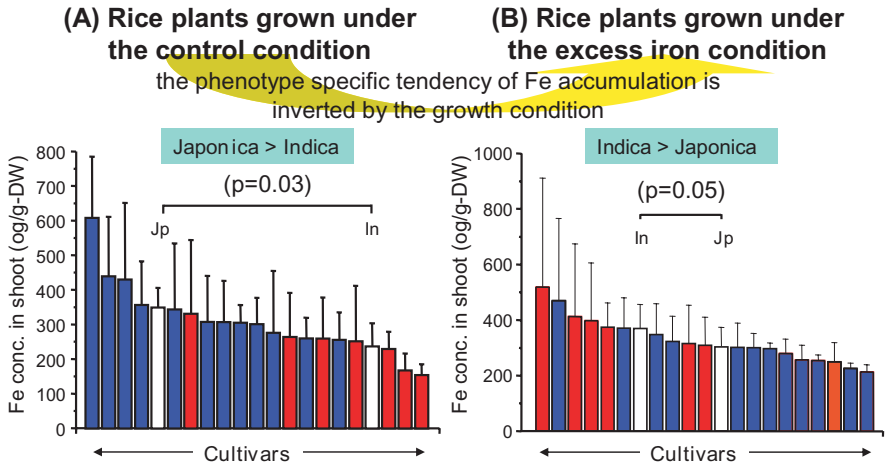


Fig.2 Differences in correlations of metal tolerances between Japonica and Indica phenotypes

Indica phenotypes (a dotted line) show higher tolerances in Zn and Cd than Japonica phenotype (a solid line). Correlation of Zn and Cd tolerances is positive in both the phenotypes (A). On the other hand, Cu tolerance is not different between these phenotypes. Correlation of Zn and Cu tolerances is positive in Japonica phenotypes, but is negative in Indica phenotype (B).



The Fe concentration in shoots grown under the control condition(A) and the excess Fe condition (B) are shown for each cultivar (N=5-15). Average and S.D. are indicated as rectangles and bars.The rectangles colored by red, blue, and white are data for Indica phenotype, Japonica phenotype and each average, respectively.

Fig.3 Iron concentration in shoots grown under the control and the excess Fe conditions

Cultivars belonging to Japonica phenotype have higher Fe concentration than those belonging to Indica phenotype under the control condition (A), whereas the tendency is inverted under the excess Fe condition (B).