How Does Aerobic Rice Mobilize Zn from Soil?

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INTRODUCTION

Zinc deficiency is a constraint to rice production worldwide. Rice production in Asia is now in transition from the traditional high water-consuming lowland rice to a promising new system of "aerobic rice" because of water shortage. New "aerobic rice" varieties are bred for this purpose. Zinc deficiency is mostly not due to low total Zn contents of soils, but more often to low Zn availability to the crop. Genotypes of aerobic rice vary widely in their capacity to take Zn up from a low Zn soil (Gao et al. 2005). This variation can be used to increase our understanding of Zn-mobilizing mechanisms by rice roots.

Plant Zn-uptake can be enhanced either by increasing the soil exploration area with mycorrhizal colonization or by root-induced chemical changes in rhizosphere. A pot and a rhizotron experiment were conducted to find out if mycorrhizal or rhizosphere effects are involved in tolerance to low Zn availability.

METHODS

A pot experiment was conducted with six rice genotypes and three mycorrhizal treatments in a factorial design with three replicates. The genotypes were selected because of their previously shown variation in Zn uptake and their similar root surface area at Zn deficiency. Mycorrhizal treatments included a non-mycorrhizal control (-AMF) and inoculation with the mycorrhizal fungus *Glomus mosseae* (BEG167) or *Glomus etunicatum* (BEG168). Plants were harvested after 8 weeks of growth on a low-Zn soil, and biomass and Zn mass fraction were determined in shoots and roots. Mycorrhizal Zn-responsiveness (MZnR) was calculated as $MZnR = [(Zn\ uptake_{+AMF} - Zn\ uptake_{-AMF}) / Zn\ uptake_{-AMF}] \times 100$.

A rhizotron experiment was conducted in a growth chamber. Treatments included two Zn levels: -Zn (no Zn) and +Zn (5 mg Zn kg^{-1} soil), and three aerobic rice genotypes. One side of the rhizotron consisted of PVC with a 5 × 5 mm grid of holes for the installation of micro-lysimeters. Soil solution from root tips was sampled with lysimeters 28 days after sowing. Organic acids in the soil solution were analysed by High Performance Liquid Chromatography (HPLC).

A clay soil (pH_{H2O} 6.5, organic matter 1.7%, DTPA-Zn 0.3 mg kg^{-1}, and P-Olsen 18.5 mg kg^{-1}) was used in both experiments. The soil for the mycorrhizal pot experiment was sterilized by autoclaving at 120°C for 2 h and air-dried. The DTPA-extractable Zn slightly increased due to the autoclaving but was on average still 0.3 mg kg^{-1}.

RESULTS AND DISCUSSION

Mycorrhizal effect

There was genotypic variation in Zn uptake among the six rice genotypes. Inoculation with *G. mosseae* and *G. etunicatum* increased Zn uptake of genotypes significantly. Inoculation with AMF did not significantly increase Zn uptake above levels that were found in genotypes with inherently high uptake capacities (data not shown). Plant Zn-uptake by non-mycorrhizal plants was negatively correlated with MZnR (Fig.1). This indicates that genotypes are responsive to AMF or have alternative mechanisms to mobilize Zn. A combination both seems impossible and may not be a feasible target for breeders.

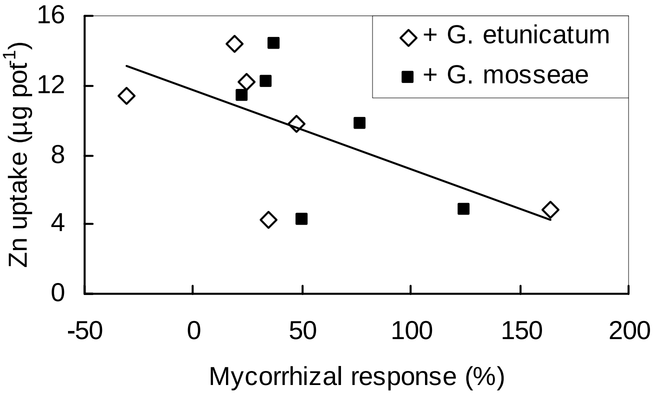

Fig. 1. Non-mycorrhizal plant Zn-uptake and mycorrhizal Zn response (Gao et al. 2007).

Rhizosphere effect

Aerobic rice genotypes responded to Zn deficiency with increased root exudation of malate. The genotype with higher Zn uptake (Hongke) showed a stronger response than the genotype with lower Zn uptake (K 150). Under Zn deficiency, a higher malate concentration was found in the rhizosphere of Hongke compared to K 150 (Fig. 2). This indicates that the genotypic difference in Zn uptake of aerobic rice might be related to the capacity to exude malate into the rhizosphere in response to Zn deficiency. In general, a higher malate concentration was found in the rhizosphere than in the bulk soil.

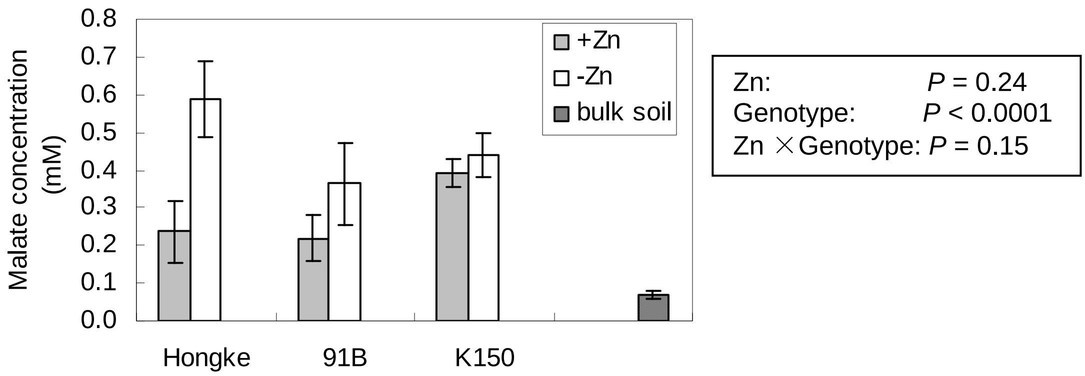

Fig. 2. Malate concentration in rhizosphere and bulk soil solution.

CONCLUSIONS

The variation in Zn uptake among aerobic rice genotypes seems related to their capacity to exude malate into the rhizosphere in response to Zn deficiency. Mycorrhizal colonization increased Zn uptake by genotypes with a low Zn-uptake efficiency. Genotypes that are less efficient in Zn uptake when nonmycorrhizal are more responsive to AMF inoculation.

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REFERENCES

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