Isotopic Discrimination of Zn during Uptake and Incorporation in Rice: Further Insights from a Field Study

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INTRODUCTION

A recent hydroponic study conducted in our laboratories demonstrated that significant isotope fractionation of Zn occurs during uptake from nutrient solutions by rice, lettuce and tomato plants (Weiss et al. 2005).

We conducted a field study at the International Rice Research Institute (IRRI) to assess if isotopic fractionation can also be found under natural conditions. This work is part of a larger study looking into the controls of isotopic fractionation of Zn and Fe during plant nutrient uptake (Chapman et al. 2006).

METHODS

Rice seedlings were transplanted into two 10 × 25 m plots at IRRI's experimental farm, Los Baños, Laguna, Philippines, the first containing a Zn-deficient soil (Typic Hydraquent from Tiaong, Quezon, Philippines), and the second containing the same soil treated with 50 kg ha^{-1} Zn in the form of $ZnSO_4$, ten days prior to transplantation. After 35 days, plants were harvested and soil directly surrounding the plant roots were collected. Plant materials and soil were air-dried at 60°C for 48 hours, and dry weights determined.

Root, shoot and soil samples were fully digested, and a partial digestion procedure was employed (0.25 g of dried powdered soil were leached in 25 ml 0.1 N HCl for 48 hours at 25°C) to assess the plant available Zn content of the soils. Following acid digestion and leaching, Zn fractions were isolated from matrix components using ion exchange chromatography. Isotope measurements were made with a ThermoElemental Axiom Multicollector-Inductively Coupled Plasma-Mass Spectrometer (MC-ICP-MS) at the NERC Isotope Geosciences Laboratories (NIGL), Keyworth, UK.

RESULTS AND DISCUSSION

For rice plants grown in Zn-amended soil, an isotopic enrichment from the soil leachate to root of +0.25 ‰ amu^{-1} occurred, followed by a depletion from root to shoot of –0.10 ‰ amu^{-1} (Fig. 1). The pattern is similar to that observed in the hydroponic study by Weiss et al. (2005), although the enrichment from the soil leachate fractions to the roots is more pronounced. Isotopic enrichment from the growth media to the root is more than twice that observed in hydroponic systems. Also, the shoot material was isotopically heavy relative to the growth media, unlike the hydroponically-cultivated shoot materials that were consistently isotopically light relative to bulk nutrient solutions. These differences suggest the involvement of the soil matrix in controlling the isotopic composition inherited by the root and shoots. Rice roots cultivated on the Zn-amended plot yielded high dry mass-Zn concentrations of ~145 $\mu g g^{-1}$ and had elevated root to shoot Zn-ratios of ~4.

Assuming the root-associated fractions reflect predominantly root-adsorbed Zn, the large Zn-isotopic enrichment from bulk soil to root for the Zn-amended soil system may be explained by the selective adsorption of isotopically heavy Zn onto charged sites within the root apoplast.

The similarity in the isotopic pattern for Zn between the Zn-amended plot and the hydroponic rice system suggests that microbial and mycorrhizial processing of Zn had no major influence on the isotopic composition of plant-available Zn.

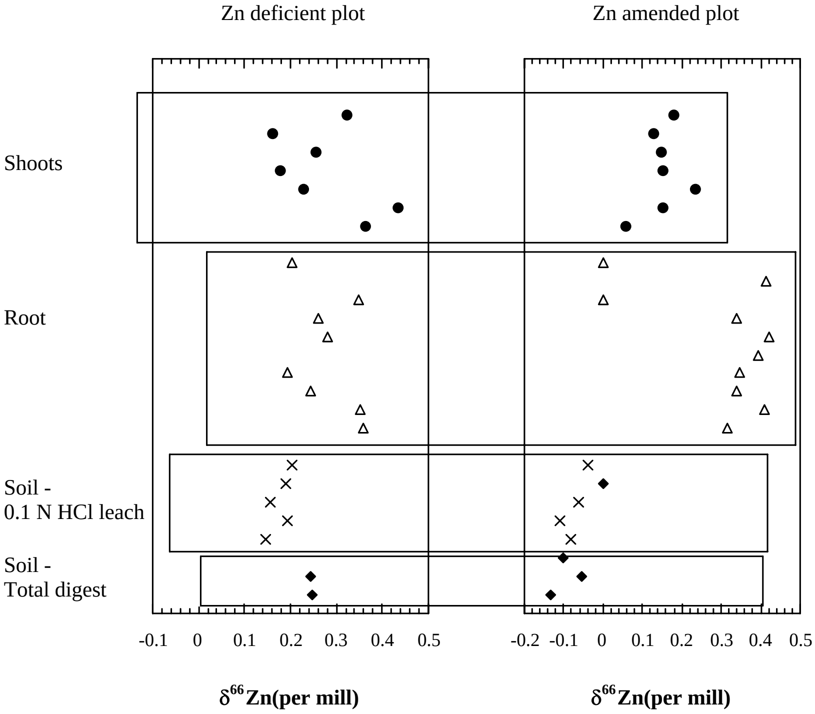

Fig. 1. Zinc isotopic fractionation within rice plants grown on Zn-deficient and fertilised plots.

The lack of isotopic variability between roots and shoots of rice plants cultivated in the Zn-deficient plot relative to the Zn-amended system and the hydroponic systems may be argued to discount significant Zn-isotopic discrimination during membrane transfer. However, membrane uptake of Zn can differ significantly with high- and low-affinity Zn-uptake pathways, therefore, offering a possible explanation for fractionation differences between the two plots.

To better understand the complex fractionation processes occurring in the root-solution environment, we further studied time dependent fractionation of Zn uptake in the Zn-hyperaccumulator species *Thlaspi caerulescens* over a period of four hours. This showed that initial heavy depletion through apoplastic adsorption is followed by a light depletion due to the kinetics of uptake.

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