The Effect of Soil Type, Zinc Fertilization and Genotype on Zinc Concentrations in Rice Grains

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INTRODUCTION

Dietary Zn deficiency has been recognized as an important nutritional disorder in members of poor households that heavily subsist on rice (*Oryza sativa* L.) with limited additional foodstuffs in their daily diet (Hotz and Brown 2004). Genetic variation in grain-Zn composition among rice genotypes could be deployed to alleviate human dietary Zn deficiencies through biofortification (Gregorio et al. 2000). The main questions addressed in this study are: i) are genotypes with the potential to accumulate Zn at high concentrations in their grains able to maintain this desirable trait when grown in soils of low native Zn status, and ii) would fertilization with Zn overcome any negative effect of a low native soil-Zn status on grain Zn concentrations.

METHODS

Field experiments were conducted on four plots with different soil-Zn levels in 2004 and 2005. Using the response in grain yield to Zn fertilizer as an indicator of soil-Zn status, the plots could be classified as highly Zn-deficient (150% increase), Zn-deficient (40% increase), and adequate (<10% increase). A fourth plot that did not respond to Zn fertilization was located in an upland field. Within each plot we compared an unfertilized (-Zn) to a fertilized (+Zn) subplot. Zinc was applied to +Zn subplots only as $ZnSO_4$ at 20 kg Zn ha^{-1}. Each subplot was planted with five rice genotypes that had been chosen to represent a whole range of grain-Zn concentrations. In ascending order of grain-Zn they were: IR74, RIL-46, IR68144, RIL-597 and Jalmagna. The experiment was designed as a split plot with 3 replications. At harvest, grains were dehulled prior to Zn determination by inductively coupled plasma-spectrometry (ICP-S). A sub-sample of grains was milled to establish the relation between brown and white rice in terms of Zn concentrations.

RESULTS AND DISCUSSION

Focussing on the genotypes IR74 (low-Zn genotype) and RIL-597 (high-Zn genotype, not significantly different from Jalmagna or IR68144) results are summarized below.

(a) Milling brown (dehulled) rice reduced Zn concentrations in grain by about 25% with little variation between genotypes. The correlation between brown and milled rice was very high (R^2=0.89) within the tested range of 20-50 µg Zn g^{-1}.

(b) Location (native soil-Zn status) was the dominant factor to determine grain-Zn concentrations (Fig. 1). Zinc concentrations observed for the genotype RIL-597 ranged from 8 µg g^{-1} in the highly deficient soil to 47 µg g^{-1} in the fertilized uplands.

(c) Genotypes had a larger effect than fertilization, and genotypic differences were most pronounced in the lowland soil with a close to adequate Zn content. However, all genotypes had a very low Zn concentration in the range of 8-11 µg g^{-1} in the highly Zn-deficient soil.

(d) The effect of fertilization varied with soil-Zn status and genotype. A significant positive effect of fertilizer application was seen in the upland soil whereas fertilization reduced seed-Zn concentrations in deficient lowland soils. This reduction coincided with a big increase in overall plant growth and grain yield and was therefore most likely due to a growth-dilution effect.

(e) The analysis of Zn concentrations in straw showed a constant positive effect of fertilization in all soils. Thus, fertilizer-Zn was taken up but not readily translocated to the seed, at least not in lowland soils.

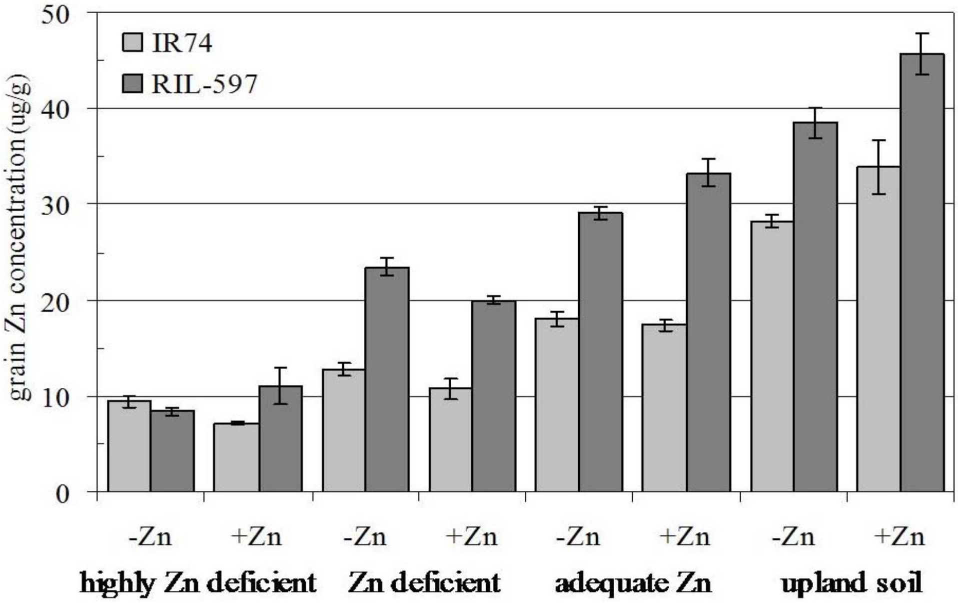

Fig. 1. Zinc concentrations in dehulled rice grains of the rice genotypes IR74 and RIL-597 as affected by native soil-Zn status and fertilization with $ZnSO_4$ (+Zn: 20 kg Zn ha^{-1}).

CONCLUSIONS

Results of this study reveal that the native soil-Zn status has a very large effect on Zn concentrations in the rice seed that cannot be overcome easily by fertilizer applications. This has implications on attempts to alleviate human dietary Zn deficiencies through biofortification. It should be possible to provide high-Zn rice to the urban poor through a combination of choosing suitable source areas (soils with a high native Zn status) and high-Zn genotypes. However, if the aim is to improve the nutritional status of rural poor, particularly people living in areas where Zn-deficient soils predominate and that are at high risk of dietary Zn deficiency, that goal may be far more difficult to achieve. It remains to be seen whether results obtained on the soils used in this study are representative of a wide variety of paddy soils. More detailed studies in target areas will therefore be needed to assess which goals can be realistically achieved.

ACKNOWLEDGEMENTS

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