From Lowland to Aerobic Rice Cultivation: Analysis of Reduced Zinc Uptake

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INTRODUCTION

Rice production in China is in transition from the traditional high water-consuming lowland rice system to a promising new system of "aerobic rice" because of water shortage. We previously demonstrated that this change in cultivation can reduce Zn uptake in crops. It is highly relevant to understand the lower Zn uptake in aerobic fields because Zn deficiency is a major problem in China, reducing crop quality and quantity.

A field experiment was conducted in combination with a soil incubation experiment to evaluate the effect of cultivation on Zn uptake by plants and to investigate the underlying mechanisms. Chemical speciation modelling is ongoing to predict the bioavailability of Zn in two cultivation systems and to predict the effects of management.

METHODS

A field experiment was conducted in Shou city, Anhui province, China. The soil was a low-Zn soil with main characteristics: texture clay, pH_{H2O} 6.5, organic matter 1.7%, and DTPA-extractable Zn 0.3 mg kg^{-1} soil. The experimental design included two cultivation systems (flooded vs. aerobic) and six rice genotypes (*Oryza sativa* L.). The experiment was laid out in a split-plot design with cultivation system as the main block and different rice genotypes as sub-blocks with four replicates. The area of each sub-block was 6 m^2 (3×2m). When harvested, crops were sampled to determine shoot dry weight and Zn mass fraction in grain and straw. At tillering stage, porewater was sampled with Rhizon soil moisture samplers (SMS MOM, Rhizosphere Research Products, Wageningen, The Netherlands) and analysed for pH and Zn concentrations.

A lab incubation experiment was done using the same soil as the field experiment. Treatments included two water regimes (flooded and aerobic) with four replicates. For flooded conditions, the soils were continuously kept flooded with a 2-cm water layer on the surface. For aerobic conditions, the soils were continually kept at field capacity by weighing. Porewater was sampled with Rhizon soil moisture samplers after 5, 42 and 148 days of incubation.

RESULTS AND DISCUSSION

Zn uptake

Plants grown in aerobic fields took less Zn up than plants in flooded fields (Fig.1). This confirms our earlier results from another field (Gao et al. 2006), indicating increased Zn-deficiency problems after a cultivation shift from flooded to aerobic conditions. The variation in Zn uptake among genotypes offers breeders a challenge to resolve Zn-deficiency problems in rice.

Zinc concentration in porewater

In porewater samples from the field and lab experiment, there was little difference in total Zn concentrations between flooded and aerobic conditions (Table 1). These results indicate that the lower plant-Zn uptake in aerobic fields was not caused by a difference in soil-Zn bioavailability. The alternative explanation might be a different Zn speciation in soil solutions between flooded and aerobic soils, different speciation in the rhizosphere, or lower transpiration rates and lower rates of Zn dissolution and diffusion in aerobic soils.

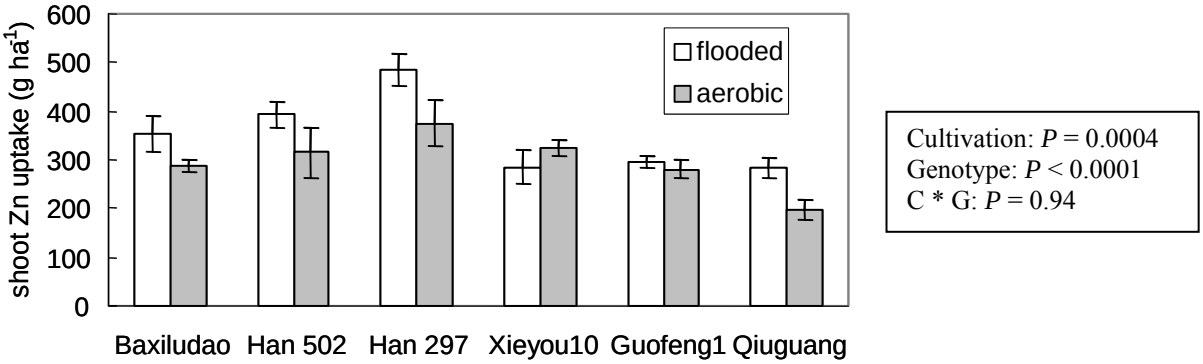

Fig. 1. Shoot Zn uptake of six rice genotypes at flooded and aerobic conditions.

Table 1. Effects of water management on pH and Zn concentration in pore water.

			pH	Zn concentration (μg L^{-1})
Field exp		Flooded	7.1	57
		Aerobic	6.1	76
		LSD	0.3	31
Incubation exp	5th day	Flooded	6.1	15.0
		Aerobic	6.7	11.1
		LSD	0.2	4.1
	42nd day	Flooded	6.7	10.1
		Aerobic	6.9	9.0
		LSD	0.2	2.3
	148th day	Flooded	6.5	8.8
		Aerobic	6.8	10.6
		LSD	0.2	0.4

Modelling results

Modelling results will be presented at the conference. Preliminary results indicate a small effect of the redox potential on soluble Zn concentrations in this soil, but a high pH dependency. This means that we have an understanding of Zn speciation depending on redox potential and pH. This will allow predicting the effects of management on Zn bioavailability.

CONCLUSIONS

The cultivation shift from flooded to aerobic may decrease Zn uptake by rice plants. This decrease is not caused by a reduction in Zn concentration in soil solution. Alternative explanations are changes in Zn speciation in soil solution, reduced plant transpiration and Zn dissolution and reduced diffusion rates in aerobic soils.

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REFERENCES

Gao, X.P., Zou, C.Q., Zhang, F.S. and Hoffland, E. (2006) From flooded to aerobic conditions in rice cultivation: consequences for zinc uptake. Plant Soil 280: 41-47.