# Reasons for Variation in Rice (*Oryza sativa*) Grain Zinc Response to Zinc Fertilization

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## INTRODUCTION

Agronomic zinc (Zn) biofortification of food crops is an important complement to genetic Zn biofortification. Wheat, especially, has shown increased grain Zn concentration in response to soil and foliar applications of Zn-containing fertilizers (Cakmak *et al.,* 2010). Response of rice to Zn fertilization has been more variable than wheat, sometimes showing minimal effect of Zn fertilization on grain Zn content (Wissuwa *et al.*, 2008).

Rice is different from all other cereal crops in two important ways: 1) it is usually grown in flooded soil; 2) it has physiological differences that affect the processes of Zn storage in stems and Zn loading into grain during grain-filling (Stomph *et al.,* 2009). The flooding of the soil changes soil redox potential, which causes a decrease the plant-availability of Zn, whether from native soil Zn or Zn that has been added to soil in fertilizer (Johnson-Beebout *et al.,* 2009), which means that soil-applied Zn fertilizer sometimes becomes unavailable to rice plants long before it can have any effect on grain Zn. Our hypothesis was that the soil-applied Zn fertilizer would be more effective at increasing grain Zn if applied when the soil was at higher redox potential.

The difference in physiology of Zn storage and grain-filling means that rice is more likely to transfer Zn taken up through the roots through the stem into the grain, making remobilization of Zn from leaves a less favorable mechanism, which means that Zn accumulated in the plant during the vegetative growth period or applied to rice leaves as foliar fertilizer may not reach the grain. There is apparent genetic variability within rice in the relative importance of root Zn uptake vs. leaf Zn remobilization (Wu *et al.,* 2010). Our hypothesis was that early-season soil Zn application was more likely to increase grain Zn content in genotypes that exhibit a high potential for leaf Zn remobilization than in those that exhibit high late-season root Zn uptake.

The objective of this paper is to present results from a greenhouse experiment that demonstrate: 1) the effect of soil redox potential on rice uptake of soil-applied Zn fertilizer; and 2) the effects of variable genotypic traits on the utilization of soil-applied Zn at different stages of plant growth.

## METHODS

This greenhouse experiment was designed in RCBD with three replicates and three treatment variables: timing of fertilizer applied to soil at 20 kg Zn $ha^{-1}$ as Zn sulfate (no added Zn, Zn added at vegetative growth stage, or Zn added at flowering stage), water management (continuous flooding, drainage 1 week prior to vegetative-stage Zn application, drainage 1 week after tillering-stage Zn application), and genotype (IR68144, IR69428). Rice was transplanted into round pots using 14-d old seedlings. Measurements included soil redox potential, available soil Zn (Johnson-Beebout *et al.,* 2009), biomass and Zn concentration of each plant part at various growth stages, grain yield, and grain Zn content. Plant samples were analyzed for Zn by ICP-OES after wet digestion.

## RESULTS AND DISCUSSION

The results from the greenhouse experiment showed that one of the two genotypes responded better to a late-season soil Zn application, while the other responded slightly better to an early-season application (Fig. 1).

Mass balance calculations of Zn in different plant parts at different times (data not shown) confirmed that IR69428 continued to take up Zn through its roots late into the season, while IR68144 had a greater potential for remobilizing Zn from leaves to grain.

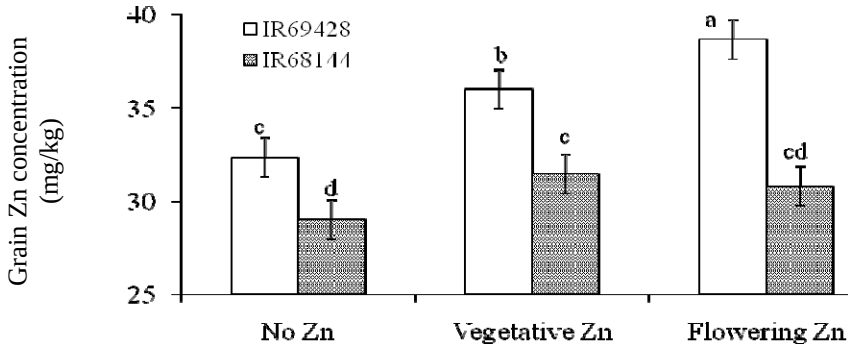


**Fig. 1. Grain Zn concentration (brown rice) of two rice genotypes in a greenhouse experiment, showing the effect of timing of zinc sulfate application to soil.**

## CONCLUSIONS

We conclude that in order to make Zn fertilization more consistently effective at increasing grain Zn content of rice, it is necessary to use soil-applied fertilizers at a time when soil redox potential is relatively high, such as during a temporary drainage period. It would also be helpful to know if the genotype has high potential for leaf Zn remobilization or high potential for late-season root Zn uptake, and to use this information to choose between soil and foliar fertilization and to determine the appropriate timing of fertilization.

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