

Influence of Different Chelates on the Accumulation of Zinc in Wheat Grain

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INTRODUCTION

A possible way to decrease Zn deficiency in humans is to increase the Zn content and bioavailability in foods. Zinc uptake can be increased by changing the physiology of Zn uptake but also by changing the concentration and speciation of Zn in the soil. For chelant-assisted phytoextractions, plants are induced to accumulate unnaturally high amounts of metals by addition of chelating agents to the soil. The metal-chelating agent complexes are able to bypass the symplastic uptake mechanism and are taken up apoplastically. The aim of this work was to study if complexes of Zn with chelating agents could enhance the total amount of Zn in the grains of wheat.

METHODS

In a climate chamber, spring-wheat (*Triticum aestivum* var. Greina) was grown hydroponically. At three different times (flower-head formation, anthesis, post anthesis), the plants were treated over two weeks with Zn plus a complexing agent (EDDS or EDTA) in the absence or presence of equimolar Fe concentrations. Each treatment comprised four replicates. To ensure that the majority of Zn was taken up as a chelate, the complexing agent (EDDS or EDTA) was added at a four times higher concentration (500 μM) than the metal (Zn 125 μM). The nutrient solution was replaced every four days. The plants were nourished with a full nutrient solution before and after the two weeks of treatment. Harvest took place at grain maturity.

The oven-dried plant material (shoot, grain) was ground in a titanium mill. The analysis of metal content was carried out by Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) after digestion with HNO_3 . The content of chelants within the plant material was measured by HPLC after extraction with hot water.

RESULTS AND DISCUSSION

The biomass of plants shoots was not influenced by the addition of chelating agents. The shoots of all treated plants had higher Zn concentrations than the shoots of control plants. The plants also accumulated significant amounts of EDDS or EDTA in their shoots. Lower concentrations of EDDS compared to EDTA were measured, presumably caused by microbial degradation of EDDS in the nutrient solution, whereas EDTA is not biodegradable.

However, the elevated Zn concentrations in the shoots did in most cases not lead to higher Zn concentrations in the grains (Fig. 1). The grains of plants treated with EDDS and Zn during flower-head formation had elevated Zn concentrations. Unfortunately, this fortification was accompanied by a reduction in yield, resulting in a reduced number of seeds. Except for another fortification in an EDDS-treatment during anthesis, none of the remaining plants exhibited enhanced Zn concentrations in the grain. Interestingly, the controls transferred a higher percentage of Zn from the shoot into the young grain compared to the treated plants. This indicates that the latter inefficiently re-translocate accumulated Zn.

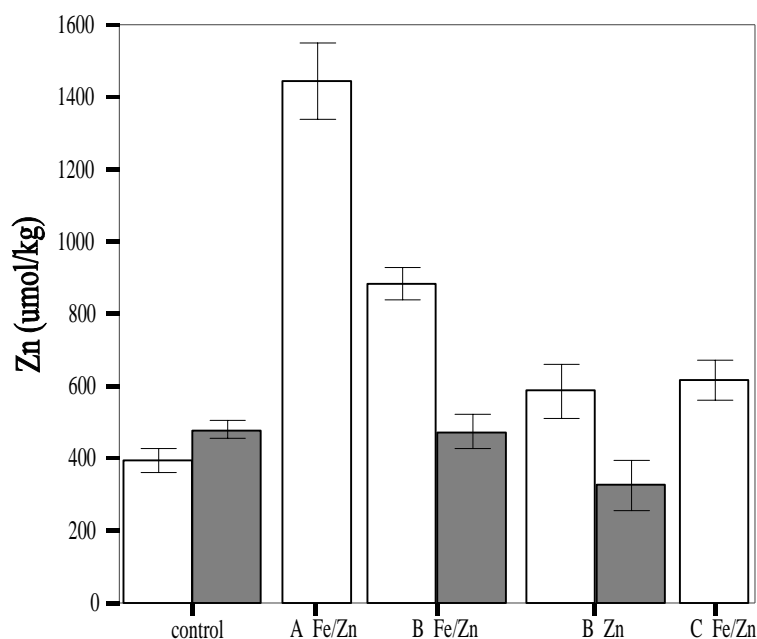


Fig. 1. Zinc concentration in the grain ($\mu\text{mol/kg}$) in presence (white bars) of EDDS and EDTA (grey bars). A, B, C indicate the three different application times (A=flower-head formation, B=anthesis, C=post anthesis). Results shown are mean values, error bars are standard error.

The amounts of EDDS and EDTA found in the grain were very small. This indicates that there was little transfer of these compounds into the symplast, which would transport them away from the main water sinks (leaves) into the grain. The apoplastic pathway, which is important for the transport of chelants into the shoots, is therefore efficiently blocked for seeds.

A comparison of chelant and total metals in shoots and grains allowed us to assess the importance of chelating agents for the transfer of metals from solution to shoots and grains. The EDTA treated plants absorbed the majority of Zn in the complexed form (ZnEDTA). To supply the developing grain with metals, these plants had to partially use complexed Zn. Extracting Zn from the complex and transporting it independently into the grain is inefficient, as indicated by lower grain-Zn concentrations in these treatments compared to the control.

The degradation of EDDS in the nutrient solutions increased free Zn concentrations. The plants rapidly absorbed the free Zn and transported it to the developing grain. This may explain the increased grain-Zn concentrations detected in the two cases mentioned above.

CONCLUSIONS

Chelants were found unsuitable to fortify wheat grains with Zn efficiently. The chelants (EDDS and EDTA) altered Zn speciation inside the plant, resulting in a restricted transfer of this metal from the shoots to the developing grain.

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