

# The Need for Innovative and Physiologically-Based Zn Fertilization Strategies for Crops

V. Römheld<sup>1</sup> and E.A. Kirkby<sup>2</sup>

<sup>1</sup> Institute of Plant Nutrition (330), University Hohenheim, 70593, Stuttgart, GERMANY  
(roemheld@uni-hohenheim.de)

<sup>2</sup> Faculty of Biology, University of Leeds, UK

## INTRODUCTION

Zinc deficiency is a widespread plant disorder occurring in distinct wild and crop plants, preferentially on calcareous soils but also on highly weathered soils with low pHs. The higher susceptibility of some genotypes to Zn deficiency is mainly due to inadequate Zn acquisition by roots. Thus, depending on soil characteristics and plant genotype, site specific crop management is a major requirement for increasing Zn availability.

## ZINC IN CROPS

### Major Functions of Zn in Plant Metabolism

Besides its basic well established functions in plant metabolism, Zn plays a specific role in pollination, as well as in the mitigation of biotic and abiotic stresses and in improving fruit quality, including the suppression of blossom-end rot in fruits by stabilizing plasma membranes together with Ca. It can be concluded from these various functions of Zn that crop plants have a higher requirement for Zn under stress conditions (high light intensity, temperature or pathogen pressure, drought or heat) and during specific developing stages. Thus, the demand of plants for Zn (spatial and or temporal) is highly dependent on specific growth and environmental conditions.

### Root Acquisition, Translocation and Retranslocation of Zn

The often observed genotypical differences in susceptibility of graminaceous plant species to Zn deficiency can be partially explained by changes in the rhizosphere. Also, the positive effect of mycorrhizae on Zn acquisition might be involved in Zn efficiency. Therefore, this knowledge should be used in rhizosphere management to improve Zn efficiency in farming practice.

## ZINC IN SOILS

### Zinc Depletion in the Rhizosphere

In most soils, Zn concentrations in the soil solution are far too low for plant requirement. Thus, mobilization processes are needed such as the release of Zn mobilizing exudates or protons by roots. These processes can be up-regulated at a low Zn status of plants, but the extent to which this occurs differs between plant genotypes. As a consequence of this discrepancy between Zn solubility in the bulk soil and plant requirement, diffusion is the main pathway for the delivery of Zn to the uptake sites at the roots, which results in distinct depletion zones of phytoavailable Zn in the rhizosphere.

A simple model calculation can demonstrate that the sustainable management of Zn without the input of Zn as fertilizers is difficult to achieve when genotypes of high efficiency in Zn acquisition are being cultivated on soils that are low in Zn. For example, crop plants with a high Zn removal ( $800\text{g Zn ha}^{-1} \text{a}^{-1}$ , e.g., sugar beet) growing in a soil derived from sandstone low in Zn ( $10\text{mg total Zn kg}^{-1}$ ) deplete without Zn application 50% of the total Zn in 20 years. In contrast, the comparative number for cereals with a relatively low Zn removal

(100g Zn h<sup>-1</sup> a<sup>-1</sup>) growing in a soil derived from basalt (with 130 mg Zn kg<sup>-1</sup>) is about 2000 years.

### **Plant Availability as Affected by the Environment**

Because Zn is mainly transported to the roots by diffusion, soil water content and root growth are decisive factors in controlling Zn acquisition. Thus, drought stress can induce Zn deficiency. The same is also true for particular herbicides such as glyphosate. An often observed phenomenon is high light-induced chlorosis at a low Zn nutritional status that is enhanced at low temperature. Other aspects that are important for an adequate plant Zn-status are well described Zn-phosphorus interactions. All of these adverse conditions that can induce Zn deficiency have to be considered in optimizing Zn fertilization.

### **CROP MANAGEMENT FOR IMPROVED ZN ACQUISITION**

For a high effectiveness of a desired Zn-management strategy it is important to imitate Zn efficient plant genotypes. This includes localized rhizosphere acidification induced by placement of nitrification-inhibitor stabilized ammonium-fertilizer together if needed with Zn salts. This will guarantee a higher solubility (*chemical availability*) of soil inherent Zn or fertilizer Zn. Also Zn-inefficient genotypes can profit from rhizosphere changes of efficient genotypes in a mixed culture. In addition, improved root growth due to using biofertilizers can increase *spatial Zn availability*. In considering spatial availability, high N and P fertilization should be avoided to achieve a high root-shoot ratio and a high release of P- and Zn-mobilizing root exudates.

If correction of Zn deficiency requires Zn application to avoid Zn depletion, Zn can be supplied as inorganic salts or as more expensive but more effective chelates, broadcasted, banded or preferentially by dressing or priming of seeds. Under stress conditions with a temporal higher demand for Zn, foliar application might be a more effective practice. In addition to these different Zn fertilization measures, long-term improvement of crop plants by selection and breeding for Zn acquisition should be followed.

### **PROSPECTS**

The outlook is good for improving strategies including rhizosphere management, adapted Zn fertilization and selection for higher Zn acquisition. These management strategies, however, should be practised on the basis of the specific role of Zn in plant physiology and have to be site specific, taking into account soil characteristics and specific crop requirement for Zn under actual stress conditions during the various developmental stages of crop growth.