Soil and Crop Management for Improving Zinc Nutrition of Crops

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Zinc deficiency is a worldwide nutritional problem in crop production. It is estimated that about 50% of world soils for cereal production have lower available Zn, which reduces grain yield and nutritional quality of grain (Graham and Welch 1996). In China, about one-third of the agricultural soils are Zn deficient. Zinc deficiency has been reported on plants grown in calcareous, desert and paddy soils where the main crops affected are rice and maize (Zou et al. 2007). Plant biotechnology and soil-crop management are essential to solve Zn-deficiency problems. The emphasis of this paper is on soil and crop management, which is important for the creation of better conditions for crop growth and for the exploitation of the biological crop-potential for Zn mobilization and utilization.

Zinc deficiency can be corrected by soil or foliar applications of Zn fertilizers, as well as seed treatments. Zinc sulphate is a common fertilizer because of its high solubility and low cost compared to Zn chelates such as EDTA-Zn (Mordvedt and Gilkes 1993). Many studies showed beneficial effects of Zn applications on crop growth and grain yield of various cereal crops. In most cases, grain-Zn concentrations do not increase to the extent that they meet human requirements even by high rates of fertilizer application (Rengel et al. 1999). Long-term fertilization with $ZnSO_4$ on an alkaline soil did not increase grain-Zn of maize (Payne et al. 1988). Similarly, only little increase in grain-Zn concentration of rice was found with soil application on a calcareous soil (Gao et al. 2006). In contrast, Zn application as soil or foliar or incorporation of both could increase seed-Zn concentration of wheat (Yilmaz et al. 1997). The extent of increase in grain-Zn concentration by Zn fertilization seemed to be influenced by crop species, crop genotypes, soil types and cultivation measures. More investigations are needed to understand these discrepancies.

Many studies showed the importance of the rhizosphere effect on Zn mobilization and uptake by plants, such as rice (Hoffland et al. 2006) and wheat (Cakmak et al. 1996). A better understanding of its underlying physiological and molecular mechanisms is needed because this could pave the way to engineer plants with enhanced capacity to absorb Zn from soils. It also offers the possibility to improve Zn bioavailability by manipulating plant rhizosphere, such as selecting Zn efficient crop and using plastic film mulching. All these approaches could increase Zn bioavailability, but more study at agro-ecosystem level could help us to explore indigenous knowledge of rhizosphere management (Zhang et al. 2004).

Cropping systems such as rotation and intercropping may have numerous advantages in terms of increasing availability of micronutrients, including Zn. In a Chinese peanut /maize intercropping example, the phytosiderophores (PS) excretion by maize into rhizosphere plays an important role in improving Fe nutrition of peanut intercropped with maize (Zuo et al. 2000). Enhanced PS release by plants may mobilize Zn in the soil and enhance Zn uptake (Zhang et al. 1991). The potential of manipulating the rhizosphere to deal with plant nutritional problems was summarized by Zhang et al. (2004), giving several case studies in major cropping systems in China as examples. Investigations are needed to qualify and quantify the role of rhizosphere processes in intercropping systems. Karlen et al. (1994) concluded that crop rotation may increase Zn availability. Mandal et al. (2000) found rice-maize rotation could use Zn fertilizer more efficiently than continuous flooded rice. However, the potential of managing cropping system to increase grain Zn should be the subject in the future.

An alternative approach to overcome Zn deficiency in crops is to exploit the genetic variation in Zn efficiency within the plant genome. The observed genetic variation in Zn efficiency among various plant genotypes offers opportunities for breeding as a tool to resolve Zn deficiency. Genetic engineering approaches have been applied to increase plant tolerance to low Zn. At present, knowledge of the genes controlling specific steps of the Zn network in soil-plant systems is still rudimentary, but increasing rapidly. Transformation and over-expression of barley (*Hordeum vulgare* cv. Golden Promise) with known Zn transporters from *Arabidopsis* can increase plant Zn uptake and seed-Zn content (Ramesh et al. 2004). Recently, a NAC gene was identified in wheat, which can accelerate senescence and increase Zn remobilisation from leaves to developing grains (Uauy et al. 2006). These results clearly show the contribution of molecular genetic tools to manipulating Zn efficiency in crops and Zn translocation into foods at enhanced levels. Breeding strategies have been developed based on these genetic findings.

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