Role of Zinc in Plant Physiology

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INTRODUCTION

Zinc is involved in a wide variety of metabolic processes, including carbohydrate, lipid, protein and nucleic acid synthesis and degradation. It does this through a large mosaic of Zn-binding motifs that orchestrate all aspects of metabolism (Auld 2001).

ZINC UPTAKE AND TRANSPORT IN PLANT TISSUES

The ZIP (Zrt-, Irt-like Protein) and CDF (Cation Diffusion Facilitator) families are important in Zn transport. The ZIP transporters were characterised in *Arabidopsis* (Grotz et al. 1998), soybean (Moreau et al. 2002) and rice (Ishimaru et al. 2005, Ramesh et al. 2003). The ZIP transporter from Arabidopsis was constitutively overexpressed in barley, resulting in increased Zn uptake in short-term experiments; the enhanced Zn-uptake capacity was lost upon increasing Zn supply, likely due to degradation of transporter molecules (Ramesh et al. 2004). Transgenic and control plants did not differ in Zn uptake in a long-term experiment. Notwithstanding uncertainties about a difference between short- and long-term effects, this transgenic approach shows great promise in increasing plant's capacity to take up Zn.

Zinc mobility in phloem is relatively high, at least in wheat (Haslett et al. 2001, Riesen and Feller 2005). Zinc has high phloem mobility from leaves to roots, stems and developing grain, and from one root to another (Rengel 2001). Tissue demand for Zn is a regulator of Zn phloem transport. Loading of Zn into developing wheat grain occurs mostly in phloem, with the transfer from xylem to phloem in the rachis and the peduncle (Pearson et al. 1995).

ZINC AND ENZYMES

Zinc is the only metal to be represented in all six enzyme classes (oxidoreductases, transferases, hydrolases, lyases, isomerases and ligases) (Auld 2001). Three primary Zn-binding motifs are structural, catalytic and co-catalytic. In structural Zn sites, cysteine is the preferred ligand. In catalytic sites, Zn forms complexes with histidine and water. Co-catalytic sites have aspartic acid and histidine as preferred ligands. The fourth type of Zn-binding site (protein interface) suggests a role of Zn in the quaternary protein structure (Auld 2001).

Several important plant enzymes [eg. Cu/Zn superoxide dismutase (SOD) and carbonic anhydrase] contain structurally bound Zn. Carbonic anhydrase (found in cytosol and chloro-plasts) catalyses the reversible hydration of CO_2. It can have 2, 4, 6 or 8 units, each with one Zn atom coordinated to histidine residues at the active site. Cu/ZnSOD is the most abundant form of SOD in higher plant cells (cytosol and chloroplast stroma). Under Zn deficiency, carbonic anhydrase (Rengel 1995) and Cu/ZnSOD (Cakmak et al. 1997) lose activity.

ZINC-CONTAINING METALOPROTEINS

Zn-metalloproteins forming a specific loop (Zn-finger motif) are regulators of gene expression. Through in silico analysis 176 Zn-finger proteins were found in Arabidopsis, with 33 of those being conserved in other eukaryotes (Englbrecht et al. 2004).

Overexpression of a Zn-finger lateral shoot-inducing factor increased lateral shoot growth by altering cytokinin concentrations in petunia, tobacco and Arabidopsis (Nakagawa et al. 2005). Expression of transgenes and endogenous genes can be controlled by Zn-finger transcription factors (TFsZF) (eg. Ordiz et al. 2002). Manipulating expression of Zn-finger proteins offers great promise in agricultural biotechnology.

DIFFERENTIAL ZINC EFFICIENCY IN PLANT GENOTYPES

Zn efficiency is the ability of plants to maintain high yield in soils with low Zn availability. A number of mechanisms may underlie Zn efficiency (Rengel 2001). Depending on experimental conditions and the plant species, the most important mechanisms may be Zn utilisation in tissues (Hacisalihoglu and Kochian 2003) and Zn uptake (Genc et al. 2006). Under Zn deficiency, Zn-efficient genotypes have a high activity of Cu/Zn-SOD (Cakmak et al. 1997; Hacisalihoglu et al. 2003, 2004; Yu et al. 1999) and carbonic anhydrase (Hacisalihoglu et al. 2003, 2004; Rengel 1995).

CONCLUSIONS

Understanding the regulation of Zn uptake and transport and the role of Zn in metabolism will be crucial in using biotechnology to enhance Zn accumulation in edible plant parts.

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