Nicotianamine in Zinc and Iron Homeostasis

Transition metals such as Fe, Zn, and Cu are essential to plants but toxic in excess, and their accumulation is tightly regulated (Palmer and Guerinot, 2009). Offering exciting possibilities for applications such as bioremediation of contaminated sites and biofortification against nutritional deficiencies (e.g., of Zn; Palmgren et al., 2008), the molecular mechanisms of metal homeostasis are beginning to be unraveled. Two recent articles highlight the chelator nicotianamine (NA) as a key player in Zn and Fe homeostasis.

Arabidopsis halleri, a close relative of Arabidopsis thaliana, is a model for Zn and Cd hyperaccumulation and hyper-tolerance (Krämer, 2010). Among several metal homeostasis genes highly expressed in A. halleri compared with A. thaliana are NICOTIANAMINE SYNTHASEs, which produce NA, a nonproteinogenic amino acid that binds a variety of transition metals. In their current work, Deinlein et al. (pages 708–723) showed that increased NA in the roots is important for Zn hyperaccumulation in A. halleri.

Deinlein et al. collected A. halleri plants from sites with a range of metal contamination levels and determined that elevated amounts of NA in the roots compared with A. thaliana is a constitutive feature of A. halleri. A. halleri RNAi lines with reduced levels of root NA had relatively higher amounts of Zn in their roots and lower amounts in their leaves, showing that root NA normally promotes root-to-shoot transport of Zn. Thus, NA in the root appears to promote root-to-shoot transport of Zn. These plants were grown on soils collected from areas of naturally occurring A. halleri populations, revealing that root NA is not likely to play a role in Zn hypertolerance, although it is needed for Zn hyperaccumulation in leaves.

In another article, Haydon et al. (pages 724–737) studied A. thaliana ZINC-INDUCED FACILITATOR1 (ZIF1), a major facilitator superfamily protein that is localized to the vacuole membrane and acts in basal Zn tolerance (Haydon and Cobbett, 2007). They found that overexpressing ZIF1 led to phenotypes reminiscent of NA deficiency, although NA levels were actually higher in the ZIF1 overexpressors. NA and Zn (see figure) accumulated in root cell vacuoles and Zn levels were correspondingly higher in the roots and lower in the shoots than in the wild type. Thus, ZIF1 overexpression led to vacuolar sequestration of NA, making Zn less available for transport from root to shoot. By contrast, Fe root-to-shoot transport was enhanced in the ZIF1 overexpressors, whereas Fe distribution within the leaf was impaired. These distinct effects of ZIF1 overexpression on Fe and Zn partitioning highlight a surprising role for the subcellular compartmentalization of a metal chelator in balancing the transport processes of two essential but interfering metals within the plant.

Together, these complementary studies point to the importance of NA in metal homeostasis, and the identification of ZIF1 as a determinant of intracellular NA distribution offers additional insight into the underlying mechanisms.

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