Plants as soil remediators

Max Planck scientists and researchers at the University of Heidelberg have discovered a gene that enables certain plants to grow on soils with high heavy metal concentrations and that even contributes to the soils' remediation.

Many new plant species have evolved over hundreds of millions of years, continuously developing new properties that enable them to grow on new and extreme habitats. Thus plants, which convert sunlight into energy-rich chemical compounds by way of photosynthesis, guarantee the continuity of life on earth. What is the basis for plants to evolve new properties and adapt to new habitats? Researchers at the Max Planck Institute for Molecular Plant Physiology in Potsdam and researchers from the Institute for Plant Sciences at the BioQuant Centre of the University of Heidelberg have just published a study that makes an important contribution towards solving this question (Nature, 15th May 2008).

Arabidopsis halleri can contribute to soil remediation

University of Heidelberg, Neuenheimer Feld (Photo: University Hospital Heidelberg)

Researchers in Ute Krämer's team at the University of Heidelberg investigated and compared the plant species Arabidopsis halleri with the closely related species Arabidopsis thaliana. The two plant species are distantly related to rapeseed and cauliflower. Arabidopsis halleri is a metal hyperaccumulator found in Germany on soils with high heavy metal concentrations; Arabidopsis thaliana is unable to store metals and cannot grow on polluted soils.

Arabidopsis halleri grows on soils where "normal" plants would die within a very short time. Rather than avoiding toxic heavy metals, Arabidopsis halleri accumulates these elements in the roots and transfers them to the upper parts of the plant storing extraordinarily high quantities in the leaves, where the highly sensitive process of photosynthesis is taking place. The plant thus makes an important contribution to remediating soils that have been polluted by mining and military activities. A. halleri is thus able to grow despite extreme conditions, even withdrawing large quantities of heavy metals from the soils.

Metal accumulation depends on the activity of a single gene

Arabidopsis thaliana (Photo: Eric Melzer)
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The scientists have now discovered that the plant loses its ability to store metal and is also less tolerant to metals if the expression of a specific Arabidopsis halleri gene is artificially reduced. The gene product is a transport protein (HMA4 metal pump) in the cell membrane that transports zinc and cadmium ions from certain root cells into the aerial parts of the plant.

Arabidopsis thaliana, which neither accumulates metal nor tolerates heavy metal, possesses a similar gene. A laboratory experiment involving the two closely related species showed that metal accumulation depends on the elevated expression of a particular gene in Arabidopsis halleri. The enhanced expression of this gene is governed by the combination of modified cis-regulatory sequences (promoter) and three-fold copy number expansion.

Different practical applications are feasible

"The clarification of the molecular mechanisms of metal hyperaccumulation can act as a model for the development of technologies enabling the natural accumulation of metals like zinc in plants. Moderate amounts of zinc are important for humans," said Ute Krämer, who coordinated the project. "But zinc is also important for plants growing on heavy metal polluted soils and hence for their soil-remediating effect." Krämer's team carried out the major part of their project at the Max Planck Institute for Molecular Plant Physiology in Potsdam before moving to the University of Heidelberg in 2007 where the group is now financed by a Heisenberg grant from the German Research Foundation. The Heidelberg Institute of Plant Sciences was established at the Centre for Systems Biology at the University of Heidelberg in 2007.

The research project also involved the research teams of Detlef Weigel at the Max Planck Institute for Developmental Biology in Tübingen, Jürgen Kroymann at the Max Planck Institute for Chemical Ecology in Jena and of Patrick Motte at the Life Sciences Institute at the University of Liège in Belgium.

Marc Hanikenne, Ina N. Talke, Michael J. Haydon, Christa Lanz, Andrea Nolte, Patrick Motte, Jürgen Kroymann, Detlef Weigel & Ute Krämer. Evolution of metal hyperaccumulation required cis-regulatory changes and triplication of HMA4. Nature, 15th May 2008; Online publication: 20th April 2008

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