

Metal armour protects plants from disease

Natural Environment Research Council

10 September 2010, by Tom Marshall

Plants can resist bacterial infection by building up toxic metals in their leaves, according to a new study.



This is the most conclusive evidence yet to show how some plants benefit from high concentrations of these metals.

'Our results demonstrate that these plants are exploiting their metal-rich environment to armour themselves against disease,' says Dr Gail Preston of the University of Oxford's Department of Plant Sciences, one of the paper's authors. 'What we've found is a direct link between these high metal concentrations and resistance to bacterial infection.'

Alpine pennycress (*Thlaspi caerulescens*), a member of the mustard family, grows in metal-rich soils like former mine workings across much of Europe. Scientists have known for a while that it takes up the metals zinc, nickel and cadmium, and that these metals build up in high concentrations in its leaves.

This 'metal hyperaccumulation' is widespread; we know of around 450 species that have evolved to do it, in many cases independently of each other. In New Caledonia in the south Pacific, a tree known locally as Sève Bleue (*Niemeyera acuminata*) has bright blue-green sap due to the high levels of nickel it contains.

But until now nobody has known how this helps the plants. A more obvious approach to living in highly metallic soil might be simply not to absorb the metals, or to accumulate them only in similar concentrations to those found in the environment. But hyperaccumulators build up levels of metal in their leaves that are many times higher than those in the soil.

And there are costs to the plants. Their existing systems for moving metals around

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Published on Chem.Info (<http://www.chem.info>)

have to work harder, and they must adapt to make sure they aren't poisoned by the metals in their own leaves.

Some scientists have suggested high levels of metal could help deter plant-eating animals or harmful microbes, but there's been little conclusive evidence for this idea.

A paper published in *PLoS Pathogens* changes this by showing that the metal accumulated in *Thlaspi* leaves makes the plant more resistant to infection by the bacterium *Pseudomonas syringae* pv. *maculicola*.

'Previously, it has been difficult to explain why *Thlaspi* plants accumulate such high concentrations of potentially toxic metals,' adds Professor Andrew Smith of the same department, who co-supervised the research. 'Our findings provide good evidence that, by accumulating metals, they benefit from enhanced protection from enemies such as pathogenic microorganisms and herbivores.'

Helen Fones, an Oxford graduate student, carried out the experimental work for the study. She grew *Thlaspi* plants in soil containing progressively higher concentrations of zinc, nickel and cadmium, and found that the more of any of these metals in a plant, the harder the bacteria seemed to find it to infect it.

By examining different strains of the bacterium in question, she then realised that the kinds that are least tolerant of these metals in the wider environment are also deterred the most from infecting *Thlaspi* by high levels of metal in its leaves.

The scientists also showed that bacteria surviving on *Thlaspi* plants on the site of a disused lead and zinc mine in Wales had more tolerance for zinc than bacteria taken from plants growing in normal soils. This suggests the bacteria are themselves evolving to adapt to the plant's defence mechanism. Preston suggests heavy metals might be 'part of an evolutionary "arms race" between plants and the microorganisms that try to colonise them.'

Preston says the group is now doing more research to understand exactly how these plants have adapted to tolerate such high concentrations of metals in their leaves. So far this suggests the plants use a part of their immune system that typically helps plants deal with disease and other environmental stress.

They have shown that *Thlaspi* plants grown on low concentrations of metal are more susceptible to infection by both fungi and bacteria. These plants also generally have a higher nutritional requirement for the metals they accumulate than other plants. This suggests they are at a disadvantage when not growing on highly metallic soil, helping explain why they are rarely found outside these environments.

Ultimately this research could have many applications. Researchers are already experimenting with the idea of 'phyto-remediation' - using plants to clean up polluted sites. If the genes for hyperaccumulation could be transferred into a plant that produces more biomass - or even if the way that plant's existing genes are

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expressed could be tweaked - then planting it on contaminated soil and then repeatedly harvesting and removing its leaves and stalks should ultimately remove the poisonous metals.

Or if valuable metals exist in small concentrations in soil, a similar method could let us use plants for 'phyto-mining' - concentrating the metals in leaves which can then be harvested and extracted.

It may also be possible to give food crops an increased ability to accumulate metals in order to increase their nutritional value. If wheat or rice plants could be given the ability to enrich their grain with metals like zinc and iron, we could protect many people around the world from malnutrition.

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