Rockcress as heavy-metal hoover

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Rockcress of the Arabidopsis halleri species shows overwhelming diversity depending on its location. Credit: Public Domain

Rockcress of the Arabidopsis halleri species is known to possess the capability of settling on hostile, heavy metal-contaminated soil. It stores extraordinary high concentrations of certain toxic heavy metals in its leaves: a rare property. Researchers from Bochum and Bayreuth have

analysed approx. 2,000 specimens of this species from 165 locations throughout Europe. In this process, they identified overwhelming diversity that has arisen among plants of the same species over the course of evolution.

Their findings help explore plants' enormous potential for future technologies; in this case, they aid the detoxification of soil and the extraction of metals that are of economic interest.

Astounding extremes of biological performance

"In plants, the natural processes of evolution have produced contrasting extremes of biological performances, as well as overwhelming biological diversity," says Prof Dr Ute Krämer from the Department of Plant Physiology at Ruhr-Universität. "However, these phenomena have been described only incompletely, and explained to an even lesser degree."

In collaboration with the research group headed by Prof Dr Stephan Clemens of Bayreuth, the Bochum-based researchers have conducted a study of Arabidopsis halleri rockcress (L.) (O'Kane and Al-Shehbaz) that is unprecedented in scope. The study focused on coupled analysis of leaf and soil samples, in order to determine the concentration levels of various heavy metal and non-heavy metal elements for each of the approx. 2,000 individual specimens in 165 locations across Europe.

Keeping a sharp eye on evolution in situ

Working on location, the researchers were able to observe the outcomes of evolution much better than in a greenhouse setting. Individuals that boast properties which are most advantageous in their home environment are better adapted and produce more progeny than their local competitors. Thus, beneficial mutations propagate. Their sampling

strategy also enabled the researchers to link the composition of the leaves directly to the composition of the local soil, allowing conclusions pertaining to the properties of each plant individual.

Researchers identify new record values

In terms of the heavy metals lead, cadmium, zinc, and copper, soil composition varied from location to location across almost five orders of magnitude. This means that the tolerable range of soil composition is enormous within this plant species. The record values of toxic heavy metals concentrated in the leaves of Arabidopsis halleri reached up to 5.4 per cent zinc and 0.3 per cent cadmium, in relation to dry biomass.

Heavy metals against defoliation

"Some plants had the sponge-like capacity of sucking out the heavy metals cadmium and zinc from mere trace amounts in the soil," describes Ute Krämer and answers the question why: "It is an unusual defence mechanism against predators or competitors; the experimental evidence gathered for an anti-herbivore effect gathered to date is the most elaborate to date ."

Czech plants accumulate more cadmium than Italian plants

Moreover, the researchers identified geographic structures in the plant properties at different scales. For example, plants growing along the German-Czech border were able to concentrate cadmium more efficiently than plants in northern Italy. Within a subset of locations, the plant individuals differed very strongly from their immediate neighbours in terms of heavy metal concentration, regardless of soil composition. The researchers suspect that this is a result of on-going evolution: diverse

adaptations of plants to specific local ecological conditions.

Genetic studies to follow

In order to prove that the differences in heavy metal concentration observed in natural habitats are the result of different properties of individuals of the species, the authors confirmed their findings in lab experiments under controlled standardised conditions. "All in all, the findings point to a surprising individuality of properties in plants of the same species," says Ute Krämer. "Now, genetic studies can be carried out, in order to determine what causes those differences and how they originate in a plant."

Future technologies on plant basis

The results of the study constitute a further step towards the exploration of the enormous potential that is hidden in natural diversity, for the future development of sustainable plant-based technologies. In this case, for example, it is feasible that plants might be deployed to concentrate metals from the soil that are of economic interest. Experts refer to this process as phytomining. Moreover, plants could be used to clean soils contaminated with heavy metals, applying a technology called phytoremediation.

Better understanding of origins

"Such specific biological phenomena are highly relevant for us humans, because they help us gain universal insights into evolutionary processes and the way they are interlinked with a highly changeable environment that is often hostile to life," points out Ute Krämer. "Quite apart from fulfilling the important function of satisfying the human thirst for knowledge with regard to our own origins and those of the surrounding

nature: these universal insights may well prove relevant for the survival of mankind in the near future."

More information: Ricardo J. Stein et al, Relationships between soil and leaf mineral composition are element-specific, environment-dependent and geographically structured in the emerging model, *New Phytologist* (2016). DOI: 10.1111/nph.14219

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