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Contrasted zinc hyperaccumulation levels between metallicolous and non-metallicolous populations of Arabidopsis halleri is driven by divergent selection

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Approximately 400 species that can survive and reproduce in metalliferous environments have developed "metal hyperaccumulation" capacity, allowing them to allocate large amounts of trace elements to their aerial parts without showing severe toxicity symptoms. The potential of hyperaccumulators to be applied in phytoremediation efforts is of great research and commercial interest. Yet, the genetic basis and evolutionary significance of this trait are to date insufficiently understood. This lack of knowledge limits the efficiency and large-scale use of such plants in reducing soil pollution through "green and clean technologies" (phytoremediation). In this context, the objective of this study was to find some evidence of selection acting on metal hyperaccumulation, thus supporting the existence of genetic adaptation for this trait.

Here, we collected six metallicolous and five non-metallicolous populations of the pseudometallophyte model species Arabidopsis halleri in Poland that are genetically and geographically close. We asexually propagated genotypes that were sampled in natural populations to produce several clones of each individual. These were subsequently used in a soil culture experiment with artificially zinc-contaminated compost for accumulation assessment. The zinc content of shoots was determined after five weeks of culture using the colorimetric reagent zincon. The heritability and the genetic differentiation of the zinc accumulation trait were estimated (Qst statistic) and the latter was compared to the differentiation at neutral molecular markers (Fst statistic).

Despite significantly ($P<0.001$) lower zinc concentrations in metallicolous compared to non-metallicolous plants, we observed a rather continuous range of zinc hyperaccumulation capacities with multiple genotypes from both edaphic types in between. Overall, zinc concentrations were high in most plants, with only a few metallicolous individuals not reaching the threshold concentration for zinc hyperaccumulation (3000 mg kg-1) under these experimental conditions. The heritability estimates of zinc concentration in shoots for each population ranged from 0.277 to 0.903, and were considerably higher in metallicolous than non-metallicolous populations. The results of Qst-Fst comparisons suggested that differences in zinc hyperaccumulation levels between metallicolous and non-metallicolous populations may be driven by divergent selection, supporting the occurrence of local adaptation. These findings encourage further genetic and genomic research to uncover the genetic basis of local adaptation of A. halleri to contaminated environments. In particular, due to their enhanced zinc hyperaccumulation capacities non-metallicolous populations may be particularly promising for phytoremediation efforts.