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Aspects of the Accumulation  
of Cobalt, Copper  
and Nickel by Plants

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Richard Stephen Morrison

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## Abstract

Hyperaccumulation of heavy metals was studied with the intention of elucidating the mechanisms of tolerance of hyperaccumulator plant species. Two main areas are covered; cobalt and copper accumulation by plants from Shaba Province, Zaïre, and nickel accumulation by species of the genus Alyssum.

In surveys of vegetation of metalliferous soils of Shaba, nine or ten new hyperaccumulators of cobalt were discovered along with eight or nine very strong accumulators. For copper, seven hyperaccumulators and five or six very strong accumulators were discovered. Some families contained a higher frequency of hyperaccumulators than others. There is also a difference in superorder classification of cobalt and copper hyperaccumulators on one hand and nickel hyperaccumulators on the other. Surveys of the genera Aeolanthus, Ipomoea and Pandiaka were made but only one new copper hyperaccumulator was found: no new cobalt hyperaccumulators were found. Several species had their abilities to accumulate confirmed.

Pot trials on three hyperaccumulators Aeolanthus biformifolius, Haumaniastrum katangense and H. robertii, showed accumulation of cobalt but not the expected accumulation of copper. The uptake curve was of the exclusion-breakdown form. The limit of breakdown, for each metal, was similar from species to species. Cobalt was less readily excluded than copper. The tolerance tests showed that some species have individuals with greatly enhanced abilities to survive higher metal concentrations than is normal for that species, while other species have more uniform tolerances. There appears to be no requirement for large metal concentrations at germination and seeds germinate more readily in the absence rather than the presence of the metals.

The distribution of cobalt and copper within leaf tissues, of five species, appears to be parallel within each species. For each metal, the distribution is parallel between different species with the exception of Buchnera metallorum. More detailed studies on cobalt in H. robertii showed the distribution to be even over the leaf area but with small anomalous regions of high concentration. The possibility that some of the cobalt was precipitated as oxalate crystals is considered. The water-soluble cobalt fraction ligand could not be identified but was not proteinaceous. It has a mass of 5,200 g per mole of cobalt.

A survey of the genus Alyssum revealed thirty-four taxa as hyperaccumulators to add to the fourteen previously known. All the taxa are from section Odontarrhena. The geographical distribution of the hyperaccumulators is discussed as is the possible evolution of hyperaccumulators in subsections Compressa and Samarifera from non-accumulators within them.

Studies of nickel accumulation by eleven Alyssum species and the closely related Bornmuellera tymphaea showed similar characteristics for all hyperaccumulators but two non-accumulators differed. A rise-to-saturation uptake form was noted. In the absence of nickel, cobalt could be accumulated with a similar uptake form. Cobalt accumulation in the presence of nickel is unknown. The rate of uptake is relatively rapid. The tolerance of hyperaccumulators to high nickel concentrations was confirmed in two types of tolerance tests; a substrate medium test and a solution test. The results from the two tests are compared.

The distribution of nickel between the plant organs is discussed. The analysis of mineral elements in leaf material showed interesting differences between hyperaccumulators and non-accumulators for calcium, magnesium and manganese content but these could not be related to differing nickel concentrations. A similar find was made for glucosinolates. An organic acid survey was restricted by the non-identification of many acids.

Separation of the nickel complexes was made. Identification of ligands involved in nickel complexation was attempted but few positive results were found. Two ligands were common in significant quantities for all species studied.

The results of these experiments were used to discuss possible evolution of hyperaccumulator species both in terms of their superorder distribution and their method of metal ion uptake. An equilibrium mechanism of uptake is proposed which involves a multiplicity of complexes for the ion absorbed. The mechanism differs from that which is commonly proposed for micronutrient elemental uptake.

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