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Heavy metal tolerance of *Cardaminopsis halleri* (L.) Hayek populations in the Polish Tatra Mts.

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Abstract

Nine populations of *Caradaminopsis halleri* growing on old mine spoil hillocks in the Tatra Mts. were studied. Five of the plant populations showed an increased content of zinc, copper and lead in shoots, in correlation with a higher contents of these elements in soil. Laboratory tests revealed the highest index of zinc-tolerance for these populations. In field zinc-tolerant populations produce stunted individuals with a decreased, by more than a half, biomass as compared with non-tolerant populations.

Key words: Cardaminopsis halleri, heavy metal tolerance, zinc-tolerance

INTRODUCTION

Population differentiation in response to soil factors has been described in many plant species. High soil concentrations of heavy metals have been shown to be a contributing factor in the development of adapted populations (Antonovics et al. 1971, Bradshaw 1976, Ernst 1976b, Bradshaw and McNeilly 1981). Investigations of metal tolerance in a species involve experimental comparison of various populations to determine the distribution of tolerance. Some investigators have tested plant populations for heavy metal tolerance by examining the rooting ability of seedlings in contaminated mine soil (Bradshaw and McNeilly 1981) or in solution culture using varying concentrations of heavy metals (Wilkins 1957, Wu and Antonovics 1975, Baker 1978, Hogan and Rauser 1979, Karataglis 1980).

Populations from metalliferous areas or metal-contaminated soils showed tolerance while populations of the same species from normal soils did not show tolerance. The species involved thus had the capacity to evolve metal tolerance rather than having an inherent tolerance (Miller 1982).

In some mountain areas of Central Europe *Cardaminopsis halleri* forms metallophytic populations (Ernst 1974, 1976a, Ellenberg 1978). However, so far not much has been done in a more detailed way on interpopulational differentiation of this species as regards various heavy metals.

The major aim of the present study was to determine whether population differentiation of that species has taken place in the area of the Tatra Mts., as there are known numerous localities of *C. halleri*, occuring both in natural communities and in areas of deposits of various metal ores exploited in the past (mainly in XIXth Century). Remainders of former mining existing till now, are the old adits, mine and spoil hillocks, more and more difficult to find in the natural vegetation (Wątocki 1951, Zwoliński 1952, Jost 1962, Gaweł 1966).

MATERIAL AND METHODS

The plant and soil materials were collected from 1983 to 1985 in the Western Tatra Mts. Using old maps and publications on old mining and metallic industry in the Tatra Mts., nine after-mining sites with *Cardaminopsis halleri* were found. These sites were usually entrise to inactive for a long time adits, as well as spoil hillocks and terraces. The vegetation cover of old mine spoils is rather scanty. The most common species are grasses: *Deschampsia flexuosa* (L.) Trin., *Agrostis capillaris* L., *Nardus stricta* L., *Festuca versicolor* Tausch, *Calamagrostis arundinacea* (L.) Roth. and *C. villosa* (Chaix) J. F. Gmelin, *Avenula versicolor* (Vill.) Lainz, *Phleum alpinum* L., *Poa pratensis* L. and *Sesleria sadlerana* Janka. Single specimens of *Picea abies* (L.) Karsten and *Abies alba* Miller grow poorly and are distinctly stunted. The growth of such decideous shrubs as *Sambucus racemosa* L. and *Sorbus aucuparia* L. is much better.

Soil samples were collected from all sites. They were dried for 14 days and then passed trough a 1 mm sieve. Soil pH was measured on 1:1 soil: distilled water mixtures. Exchangeable and soluble metals (Zn, Pb, Cu) were extracted by shaking with 0.1 M ammonium acetate solution (pH 7) for 1 hour. Concentrations of metals were measured in the filtrate (three replicates) using the AAS method. Plant materials from all populations were dried and then mineralized by means of a mixture of nitric and perchloric acids (4:1). Concentrations of Fe, Mn, Zn, Cu, Pb, Ni and Co were measured (three replicates) using an atomic absorption spectrophotometer.

Heavy metals tolerance of nine populations was estimated from dry weight measurements of plants collected from their natural sites.

Tolerance to zinc was tested by measuring its effect on root growth. Batches of 100 seeds of each population were sown in Petri dishes on a 1 g·dm^{-3} calcium nitrate solution with (2 ppm) and without zinc added as zinc sulphate. The experiment was carried out in three replicates in constant light (15000 lux) and temperature (21°C). Eleven days after sowing the radicle lengths of all germinated seeds were measured and means calculated for each treatment. An index of zinc tolerance was obtained by the ratio:

$$\frac{\text{Mean radicle length in zinc treatment}}{\text{Mean radicle length in control solution.}}$$

RESULTS AND DISCUSSION

The amounts of extractable zinc, lead and copper in the soil samples correlate distinctly with the content of the same elements in the dry weight of the plants (Tables 1 and 2). In sites marked as 2, 3, 4, and 9 so in soil as in plants the concentration of Zn, Cu and Pb is markedly

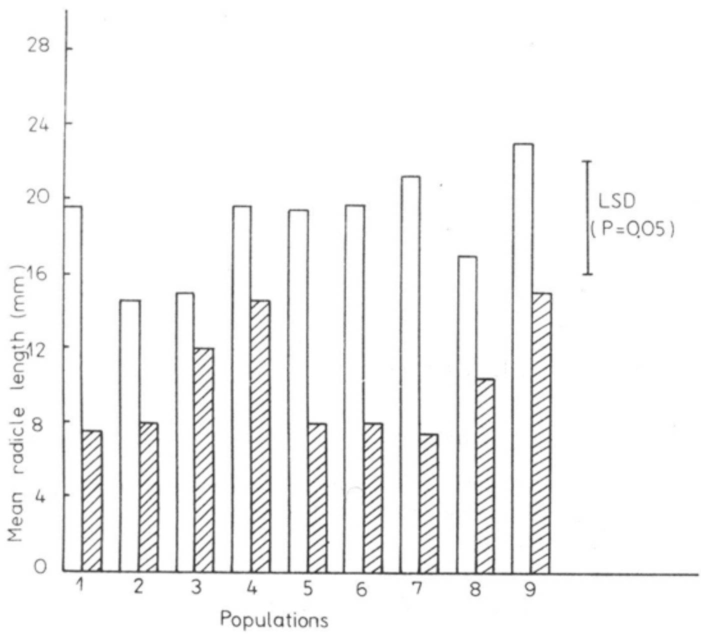

Fig. 1. The effect of 2 ppm Zn in 1 g·dm^{-3} calcium nitrate solution on radicle elongation in seedlings of nine *Cardaminopsis halleri* populations, 11 days after sowing. Hatched columns — Zn treatment, white columns — control. For populations explanation see Table 1 and 2

higher, but zinc and copper showing the highest concentration. The highest content of lead in soil and plants in site 1, at a relatively low amount of Zn and Cu is probably due to airborne pollution, since not long ago it used to be a place with intense vehicular traffic.

The content of heavy metals in soil and in plants suggest clearly that in the places studied the particular populations of *Cardaminopsis halleri* are, above all influenced by zinc, to which the plants react by cumulating this element in shoots. The suggestion that the species studied may form in the Tatra Zn-tolerant populations finds confirmation in the results of laboratory investigations, where the mean length of radicles and the index of zinc tolerance were studied (Figs. 1 and 2). In the last day of experiment with seedlings the length of the radicles was considerably differentiated between the studied populations of *C. halleri* (Fig. 1). The differences in rate of seed germination from particular sites (and at the same time the differences in radicle lengths) result probably from the physiological reaction on treshold amount of the heavy metal (Mathys

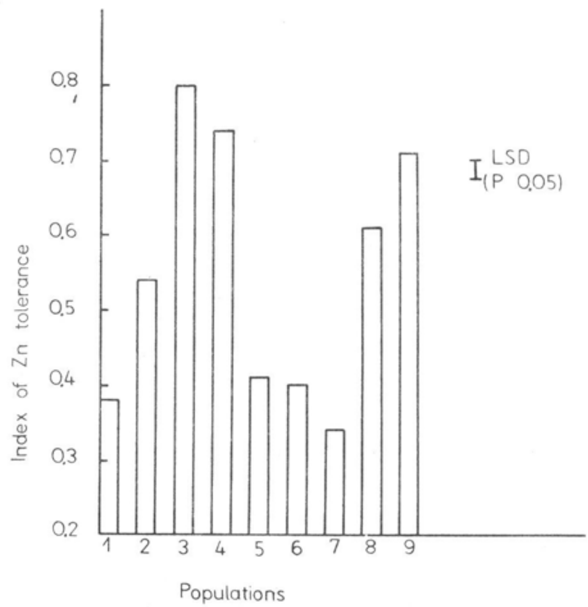

Fig. 2. The zinc tolerance index of nine *Cardaminopsis halleri* populations. For populations explanation see Table 1 and 2

1980). It is of interest that the populations from metalliferous places, showing an increased cumulation of zinc, appear to be resistant to the contents of this metal: this is revealed in a lower inhibition of radicles growth as compared with the remaining populations. The tolerance index distinguishes best the group of zinc-tolerant populations from Tatra localities most rich with this metal (Fig. 2).

From studies carried out hitherto no explicit answer can be drawn whether *C. halleri* is, anywhere in Europe, a clear indicator of naturally metalliferous soils (Ernst 1974). Anthropogenic localities of this species related with the presence of lead, and even a separate community in

Table 1

Examined sites, soil pH and 0.5 M ammonium acetate extractable zinc, lead and copper concentrations in the soil samples (ppm)

No	Name of site	Elevation, m	pH	Zn	Pb	Cu	Type of site
1.	Kuźnice	965	7.0	38	6.5	12	grassy stream side
2.	Jaworzynka Valley (Herbik)	1202	6.7	380	1.6	6	old adit terrace
3.	Ornak 1 (Wolarnia)	1450	6.5	490	2.5	18	old mine hillocks
4.	Ornak 2 (Baniste)	1490	6.5	540	2.8	18	old mine hillock
5.	Pyszna Pasture („Kunszty")	1180	6.1	19	0.5	4	edge of spruce wood
6.	Kościeliska Valley (Stare Kościeliska)	960	6.6	16	0.4	4	open grassland
7.	Chochołowska Valley (Huciańskie Banie)	1170	6.4	22	0.3	2	old mine spoil hillocks
8.	Stoły Pasture	1320	6.6	612	1.2	16	open grassland
9.	Starorobociańska Valley (Rówień)	1340	6.2	580	1.8	9	old mine spoil in spruce wood

Table 2

The amounts of some heavy metals in *Cardaminopsis halleri* shoots collected from different sites

No	Name of site	Heavy metals, ppm						
		Fe	Mn	Zn	Cu	Pb	Ni	Co
1.	Kuźnice	3700	840	95	12	3.5	trace	trace
2.	Jaworzynka Valley	4800	670	315	87	3.0	trace	trace
3.	Ornak 1	6500	820	470	43	2.8	trace	trace
4.	Ornak 2	6200	1020	390	70	3.0	1.8	trace
5.	Pyszna Pasture	2400	670	70	10	1.2	0.2	2.0
6.	Kościeliska Valley	1250	915	60	8	0.2	0.2	8.0
7.	Chochołowska Valley	2450	900	40	8	0.2	0.1	trace
8.	Stoły Pasture	6700	817	340	16	1.0	6.0	trace
9.	Starorobociańska Valley	6900	1040	350	18	1.0	1.0	4.0

conditions of Pb contamination, were described by Hülbusch and Hülbusch (1980). However, there are many lowland nd mountainous stands of *C. halleri* not connected with an increased contents of metals. Those Tatra sites which show a higher contents of metal in soil should be regarded as man-made: through such acivities mine spoils became top soils. Natural metal are deposits are localized beyond the reach of the plants' root system. This was confirmed also by the studies of Godzik (1984) carried out on population of *Biscutella laevigata* L. collected in the Tatra Mts.

The increased metal-tolerance, especially to zinc, recorded in five of the populations studied, is probably a new phenomenon, connected with mine excavations. It can be assumed that the interspecific competition displaces

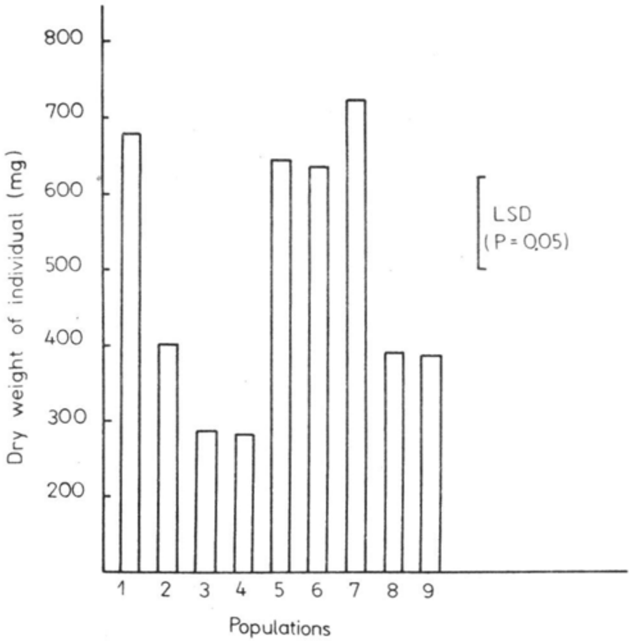

Fig. 3. Dry weight of mean individual from different populations of *Cardaminopsis halleri*. Values of means of five replicates. For populations explanation see Table 1 and 2

some of the *C. halleri* populations to habitats disadvantageous to other plants, forming in result Zn-tolerant populations. The disadvantageous conditions in which the new, metal-resistant populations are forced to exist find confirmation in the reduced biomass of the plants (Fig. 3). The loss of biomass may come up to more than a held as compared with non-tolerant populations. The decrease of biomass in plants from metalliferous areas in described, among others, by Antonovics et al. (1971) and Mathys (1980). The occurence in the Tatra Mts. of *C. halleri* populations of decreased biomass, which are resistant to the contents of heavy metal.

seems to point to a not yet settled, probably still developing process of tolerance.

According to the suggested by Baker (1981) scheme of life strategies of plants in response to heavy metals the Tatra populations are neither "accumulators" nor "excluders", instead they can be qualified as "indicators". They indicate the presence of abnormal concentrations of heavy metals, especially zinc, in the Tatra Mts.

Plants belonging to the metal-tolerant population approximate taxonomicaly the var. *tatrica* Pawł. (= var. *devestita* Zap. p.p.) described by Pawłowski (1956), though there are among them individuals showing intermediate traits in relation to typical species.

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Tolerancja na metale ciężkie populacji Cardaminopsis halleri (L.) Hayek w Polskich Tatrach

Streszczenie

W latach 1983-1985 badano w Tatrach rozmieszczenie *Cardaminopsis halleri* na terenie starych wyrobisk górniczych. Wśród 9 zbadanych populacji okazało się, że jedynie 5 wykazuje tendencje do kumulowania metali ciężkich, a zwłaszcza cynku. Badania laboratoryjne potwierdziły istnienie mechanizmu tolerancji u niektórych tatrzańskich populacji tej rośliny. Zastosowany test wzrostu korzeni sugeruje, że pewne populacje charakteryzują się trwałą tolerancją na podwyższone zawartości cynku. Rośliny z populacji tolerujących zwiększone ilości metali w podłożu cechował karłowaty wzrost, odbijający się na ich biomasie; biomasa tych roślin była co najmniej o połowę mniejsza w porównaniu z populacjami nietolerancyjnymi.