Elemental mapping revealed different adaptation strategies in seed of Zn hyperaccumulating plant *Arabidopsis halleri* from Poland

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Objectives

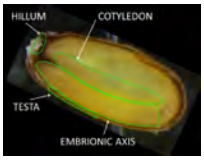
Arabidopsis halleri (L.) Brassicaceae is a European, perennial plant with significant heavy metal tolerance and ability to hyperaccumulate Zn and Cd (Pauwels et al. 2012). This species is a pseudometallophyte, thus can be found on both metalliferous and non-metalliferous sites (Meyer et al. 2010). In spite of extensive related work that has been carried out on *A. halleri* in different fields there is no data concerning chemistry and elemental distribution in seeds of this species.
The aim of this study was to compare the elemental concentration and distribution in seeds from populations of *A. halleri* growing naturally on sites heavily polluted with Zn (Bolesław and Galman) and clean, control sites (Tatra Mountains and Niepołomice Forest). Samples were collected during summer 2015.

Methods

Three seeds per population were analyzed using the nuclear microprobe at the Materials Research Department of iThemba LABS. PIXE (Particle Induced X-ray Emission) and EBS (Elastic Backscattering Spectrometry) were simultaneously used. Data were acquired in the event-by-event mode. A proton beam of 3.0 MeV energy and a current of 200-300 pA was focused to a 3 μm × 3 μm spot and scanned over seeds. Data evaluation was performed using GeoPIXE II software. Quantitative elemental maps were generated using the Dynamic Analysis method.
Concentrations and distribution of P, S, Cl, K, Ca, Mn, Fe, Cu and Zn in the seed sections were obtained. The analysis of micro-PIXE maps of elements' localization in *A. halleri* seed sections was carried out on ten separated regions: testa with extracted hilum, chalazal and micropylar region, embryonic axis with root tip and hypocotyl, cotyledons and vascular tracts of cotyledons, and the root.

Localization of studied populations of *Arabidopsis halleri*

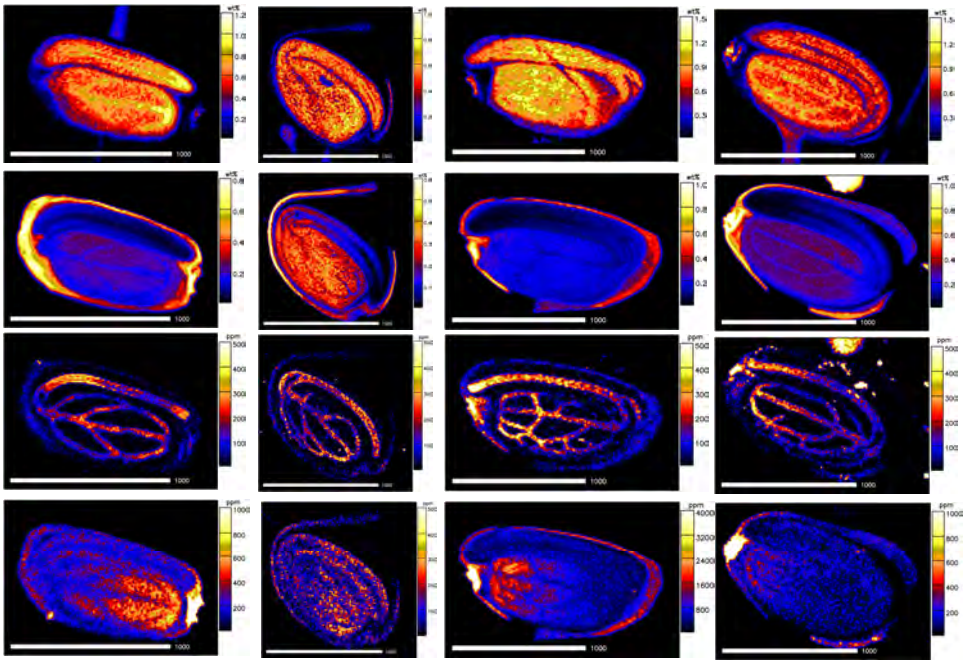

Arabidopsis halleri



Main seed regions selected for analysis

Concentrations of selected elements in seeds of *A. halleri* for populations from polluted and clean sites (weighted mean value ± error, N=3) and the total concentrations in the soils from these sites (Kostecka 2009).

		Polluted sites		Clean control sites	
		Bolesław	Galman	Niepołomice Forest	Tatra Mts.
		[ppm]			
P	Whole section	4010±160	3730±140	4600±170	4560±160
	Embrionic axis	5890±180	5020±180	1240±60	6230±190
	Cotyledon	6110±190	5560±180	7110±240	6430±210
	Testa	610±50	490±25	130±20	620±40
	Hilum	1540±60	445±25	4240±170	1300±60
	Soil	800±100	1300±100	700±100	900±100
Ca	Whole section	2360±20	2380±17	2180±20	1070±13
	Embrionic axis	1320±16	1320±16	1260±15	390±7
	Cotyledon	2300±20	2900±20	2460±20	370±7
	Testa	5230±20	3710±18	3180±16	4470±18
	Hilum	5470±20	3620±20	7350±30	6740±25
	Soil	8200±2200	60700±20100	5700±3400	6600±2800
Fe	Whole section	62±2	51±1	60±1	110±4
	Embrionic axis	91±3	35±2	85±3	85±3
	Cotyledon	59±2	71±2	62±1	77±2
	Testa	35±1	16±1	16±3	34±2
	Hilum	113±5	43±3	312±8	264±5
	Soil	12200±1000	19300±3600	17000±1700	27200±3900
Zn	Whole section	100±5	89±3	314±10	59±3
	Embrionic axis	144±7	128±5	217±10	99±4
	Cotyledon	90±5	109±5	225±10	52±3
	Testa	81±3	50±3	300±11	49±2
	Hilum	356±13	110±5	3400±60	185±8
	Soil	3910 ± 340	35900 ± 27400	170 ± 20	125 ± 20



Quantitative elemental maps of seed cross-sections from polluted sites (Bolesław and Galman) and clean control sites (Niepołomice Forest and Tatra Mts.). Scale bar: 1000 micrometers; concentrations in ppm or in wt% dry mass.

Results and discussion

1. Unexpected differences were found in the Zn concentrations and distribution between populations:
- the highest Zn concentration of the whole seed cross-sections and in all analyzed regions were found in population from clean, control site (Niepołomice Forest), growing on soil with a very low amount of Zn,
- to the contrary, very low Zn concentrations of the whole seed cross-sections were detected in populations growing on polluted sites (Galman and Bolesław); in particular, the lowest concentration in hilum was detected in population from the extremely polluted site of Galman.

The adaptation mechanism to hostile, polluted environment demonstrates exclusion of toxic amounts of Zn from seeds.

2. Hilum was always place of highest Zn enrichment – in all populations from clean and polluted soils, which suggests important role of hilum in regulation of the uptake.

3. Analyzed elements showed diverse pattern of distribution within seed section:
- the highest enrichments of Fe were found in pravascular strands of the hypocotyl, radicle and cotyledons
- there is positive correlation between Zn and P in hilum from population growing on clean control site (Niepołomice Forest) and population from extremely polluted site of Galman
- calcium was accumulated mainly in the hilum and testa, and P mainly in cotyledons.

Funding

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Literature:

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