Leptodontium gemmascens: a metal-tolerant moss or a pure metallophyte?

Dirk De Beer, **Kasper Van Acker** and **Tobias Ceulemans** present some fascinating new information about the habitat of this global rarity in Belgium

△ Figure 1. Habitat of *L. gemmascens*, Lommel-stort. *Dirk De Beer*

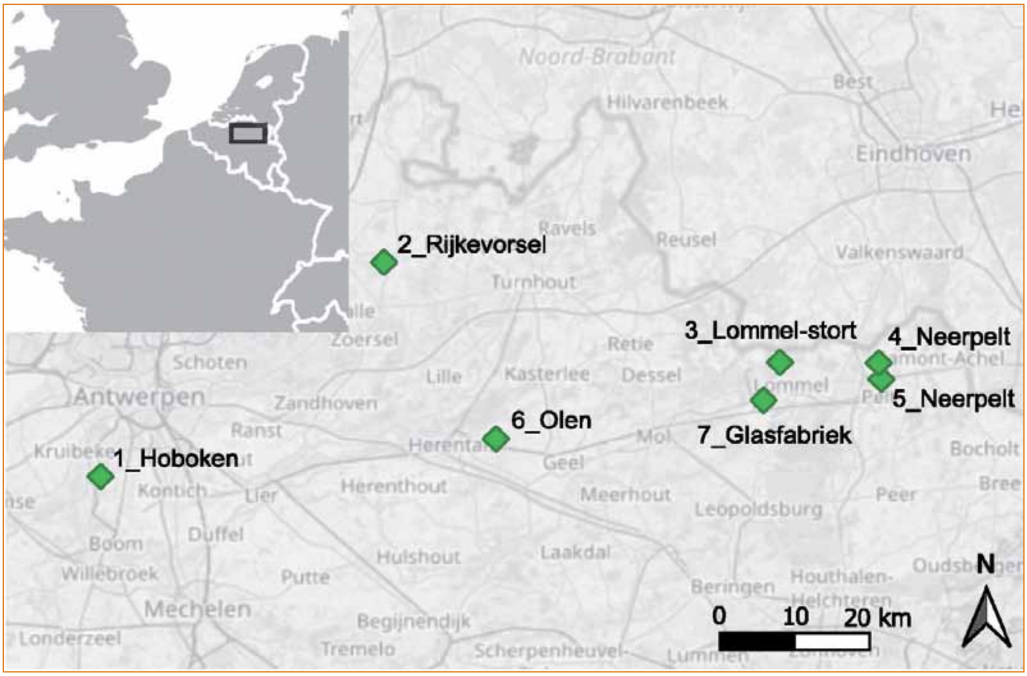
Three species of the genus *Leptodontium* naturally occur in Europe: *L. flexifolium*, *L. gemmascens* and *L. styriacum* (Frey *et al.*, 2006). The last species is known from Austria and Switzerland and is considered to be closely related to *L. flexifolium*; some authors synonymise these two species (Ignatov *et al.*, 2005). In addition, *L. proliferum*, a species from the southern hemisphere, is restricted to just one site in Britain (Porley & Edwards, 2010).

Whereas *L. flexifolium* is rather frequent in western Europe, including Britain and Ireland, Denmark, Germany, Netherlands, Belgium, Luxemburg and France, *L. gemmascens* appears to be much rarer. Having previously been observed only in Britain, it spread into western Europe in the last decades of the 20th century (Schneider *et al.*, 1998). The first observation of *L. gemmascens* in Belgium dates from 1991 (Arts *et al.*, 1992) and currently there are 15 known Belgian populations. In the Campine region, north-east Belgium, which is primarily a sandy region characterised by heathlands and acidic forests, *L. gemmascens* has been documented in four locations since 2009, sometimes with large populations covering more than 10 m^2 (Figs 1–4).

△ Figure 2. *L. gemmascens* with gemmae, Lommel-stort. *Leo Van Herbruggen*

▽ Figure 3. Habitat of *L. gemmascens*, Pelt. *Kasper Van Acker*

▽ Figure 4. *L. gemmascens* on decaying leaves of *Molinia*, Pelt. *Kasper Van Acker*



△ Figure 5. Distribution of *L. gemmascens* in the Belgian Campine region.

All *Leptodontium* species are mosses of acidic substrates. They typically occur on decaying organic matter from grasses on heathland, but are also found in anthropogenic habitats such as roofs consisting of weathered thatch (wheat, reed). However, the newly discovered populations in the north-east of Belgium are all situated in degraded heathland sites which probably have a strong historical contamination of heavy metals owing to historical lead and zinc industrial refining activity (Sites 1, 3 and 4/5; Fig. 5). There is only one exception: Site 2 is located in a nature reserve in sod-cut heathland, where the litter layer was removed as a heathland restoration measure. Here we test the hypothesis that heavy metal contaminated soils have provided a novel anthropogenic habitat for *L. gemmascens*. Therefore, we visited the four known populations (Sites 1, 2, 3 and 4/5) and also performed a targeted search for populations of *L. gemmascens* across two additional, pre-selected sites with presumed historical heavy metal pollution (Sites 6 and 7).

Materials and methods

We carried out terrain surveys at six different sites, four sites with known populations (Sites 1, 2, 3 and 4/5) and two newly selected sites in the vicinity of industrial metallurgy activity (Sites 6 and 7). At each of the sites where we found the moss, a soil sample was taken in a 5 × 5 cm plot. From this sample we made an A-sample, consisting of the layer of organic detritus where the moss was growing, and a B-sample, consisting of humus-rich sand just beneath the surface of the organic layer. At one site, Neerpelt, two different plots were established (4 and 5). As a comparison with an unpolluted site, sample

Table 1. Heavy metal content of samples (ppm). Exceedances of more than five times the benchmark values are shown in bold.

No.	Location	As	Cd	Co	Cr	Cu	Ni	Pb	Zn
Vlarebo benchmark values		35	1		91	72	48	120	200
0	Oud-Heverlee	1	1	1	4	13	3	3	74
1A	Hoboken	85	**79**	12	16	**1822**	117	**7114**	**1079**
1B	Hoboken	**140**	**33**	5	16	**678**	46	**3773**	404
2A	Rijkevorsel	11	1	3	15	58	18	242	225
2B	Rijkevorsel	5	0	1	7	17	2	56	12
3A	Lommel-Stort	6	4	3	9	41	7	190	441
3B	Lommel-Stort	9	3	5	10	94	9	202	222
4A	Neerpelt	15	3	1	8	38	4	160	430
4B	Neerpelt	22	2	2	9	87	7	254	311
5A	Neerpelt	13	4	1	6	52	5	256	691
5B	Neerpelt	18	**10**	3	15	107	18	**900**	**1627**
6A	Olen	32	**10**	**603**	17	**1265**	125	115	776
6B	Olen	42	4	**335**	27	**610**	43	132	275
7A	Lommmel Glasfabriek	21	**14**	2	10	109	5	**1104**	**1701**
7B	Lommmel Glasfabriek	10	1	1	8	27	2	200	128

0 was taken from organic detritus in a nature reserve south of Leuven.

All soil samples consisted of 100 mg dried material which was digested in 2 ml nitric acid (68% Trace Metal grade) using a Stuart Block heater. The near dry solution was finally diluted to 10 ml using a HNO3 0.1% solution. These were analyzed on a ICP-OES for As, Cd, Co, Cr, Cu, Ni, Pb and Zn (Varian 720ES).

Results

We found two new populations of *L. gemmascens* (Sites 6 and 7), resulting in six known populations in the Campine region. The two sites of Neerpelt were considered to belong to the same population (Sites 4 and 5).

The results of the analysis of the soil samples were compared with representative benchmark values (Vlarebo, 2008) to be targeted after land remediation of contaminated soils (Table 1). In all samples, several heavy metals were measured which greatly exceeded the safe reference values, especially cadmium, copper, lead and zinc. Exceedances of more than five times the benchmark values are shown in bold in Table 1. The most striking sample, 1A in Hoboken, exceeded the benchmark for cadmium, copper and lead by at least a factor of 20. Only the B-sample, from Rijkevorsel (Site 2), was less polluted. This was the only site in a nature heathland reserve, all other sites were fallow former industrial sites. Despite the nature reserve status and the extant heathland vegetation, the A-sample of Site 2 still exceeded the benchmark for cadmium, lead and zinc. This is probably a result of dust from the nearby metal recycling plant. All other sites had important exceedances in one or more heavy metal values.

Discussion

Our observations indicate that *L. gemmascens* shows a high tolerance to heavy metals, at least in the north-eastern sites of Belgium. Mosses are very sensitive indicators of the ions present in the substrate on which they grow. Some species are known as pure metallophytes, species that only occur where high concentrations of heavy metals are present. Well-known examples are *Bryum pallescens*, *Cephaloziella massalongoi*, *C. nicholsonii*, *Ditrichum cornubicum, D. plumbicola, Grimmia atrata*, *Mielichhoferia* spp. and *Scopelophila cataractae* (Porley & Hodgetts, 2005; Bates, 2009). Some species have been identified as tolerant to metals to a certain degree, or potentially exhibit metal-tolerant ecotypes. This is, for instance, the case for *Ceratodon purpureus*, *Cephaloziella divaricata*, *Dicranella varia* and *Pohlia nutans* (Tyler, 1990).

It has also been observed that metal tolerance of mosses is dependent on the region. For instance, *Didymodon australasiae* is a ruderal species in the Mediterranean, but seems to be an obligate metallophyte in the old mining areas around Liège in Belgium (De Zuttere *et al*., 1987). Our results indicate that the same is the case for *L. gemmascens* in the north of Belgium. At all known locations of the species, we found high to extremely high concentrations of heavy metals. Our observations are at odds with the presumed sensitivity of *L. gemmascens* to zinc wiring of thatch roofs in Britain, where metal toxicity is assumed to be responsible for the decline of *L. gemmascens* on thatch roofs (Porley, 2009; Lansdown & Rumsey, 2021).

We offer two possible hypotheses regarding this apparent contradiction in the ecology of this rare moss species. Either *L. gemmascens* is a true metal-tolerant moss that has found a suitable niche in polluted industrial sites, as it is a species that is susceptible to high competition for light. As primary production of other plant species is restricted by high concentrations of heavy metals, such sites provide a suitable habitat for poorly competitive moss species. Such a mechanism is well-known for several small-statured heavy metal-tolerant higher plant species such as *Festuca guestfalica* subsp. *guestfalica*, *Noccaea caerulescens* subsp. *calaminaris* and *Viola calaminaria* on lead and metal spoil in Belgium and Germany (EUNIS habitat classification 2019: Heavy-metal grasslands). Besides the pollution itself, decomposition of organic matter will slow down because of the reduced number of invertebrates in polluted sites, creating in this way a suitable habitat for *Leptodontium*. Following this hypothesis, the decline of *L. gemmascens* on thatch roofs in the United Kingdom is likely to have been caused by an environmental driver other than zinc leakage from roof wiring (Porley, 2009; Lansdown & Rumsey, 2021). Furthermore, a targeted survey of metal-polluted sites across Europe, including the many lead spoils in the United Kingdom, is recommended.

On the other hand, it is possible that the populations of north-east Belgium consist of a previously unknown ecotype of *L. gemmascens* that has evolved metal-tolerance similar to *D. australasiae* (De Zuttere *et al*., 1987). A common garden experiment with clones of Belgian metallophytic populations, together with British and non-metallophytic populations, exposed to a gradient of increasing metal concentration, could confirm or falsify this hypothesis (Jiménez-Ambriz *et al*., 2007).

We conclude that at least the Belgian Campine populations of the rare *L. gemmascens* appear to be resistant to high concentrations of heavy metals and that the species can occupy an ecological niche in this anthropogenic habitat which was previously unknown. We recommend targeted surveys for this species at metal polluted sites across Europe and a common garden experiment to unravel the precise mechanisms involved.

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