Examination of *Blepharis aspera* as a possible Cu–Ni indicator plant

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BLEPHARIS ASPERA WAS COLLECTED FROM A copper–nickel mineralized area in Botswana and examined as a possible Cu–Ni indicator plant for biogeochemical prospecting. Different plant parts and the host soils were analysed using ultrasonic slurry sampling electrothermal atomic absorption spectrometry. All plant parts accumulated Cu and Ni in above-normal amounts, although not in hyperaccumulator concentrations. The leaf to soil concentration ratio varied little with metal concentration in the soil. We propose *Blepharis aspera* as a Cu indicator plant. The accumulation behaviour of *Blepharis aspera* is compared with another previously studied metallophyte, *Helichrysum candolleanum,* that is growing in the same area.

Introduction

We present the results of a study of *Blepharis aspera* Obermeyer (family Acanthaceae), whose occurrence has not been reported in Botswana before, as a possible Cu–Ni indicator plant. Recently,[1] a similar Cu–Ni study was carried out on two metal-tolerant plants (metallophytes) —*Blepharis diversispina* (Nees) C.B. Clarke (Acanthaceae) and *Helichrysum candolleanum* H. Buek (Asteraceae)—in which the latter was reported to be a possible Cu–Ni indicator. Metallophytes cope differently with high levels of metals in the soil, and therefore it is desirable to establish the metal tolerance of these plants. There are various types of metal-tolerant behaviour (displaying exclusion, accumulation and indicator) of plants that grow in mineralized soils.[1–3]

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Experimental

Blepharis aspera is a shrub with purple-bluish flowers (Fig. 1). It was identified at the Royal Botanic Gardens, Kew, U.K. (voucher number 03SEL BD1). It grows in Zimbabwe and northern parts of South Africa.[4,5] The plants and the host soils analysed were collected from Selkirk, an active copper–nickel mine, in northeastern Botswana, on three sampling trips carried out on 13/14 November 2002, 12/13 March 2003 and 20/21 August 2004. The samples were air-dried and ground to a fine powder (less than 63 μm).

Copper and nickel were determined using a Perkin-Elmer Zeeman atomic absorption spectrometer (AAnalyst 800, PE; Überlingen, Germany), set at 222.6 nm for Cu and 232.0 nm for Ni, and ultrasonic slurry sampling ETAAS with dilute nitric acid and Triton X-100 diluent. Certified reference materials were used for method validation. Details of the analytical procedure were described previously.[1]

Results and discussion

Of the four sampling locations visited in Botswana (Selkirk, Thakadu, Malaka and Nakalakwana), *B. aspera* was found only at Selkirk, which had high soil Cu and Ni concentrations in the range 0.38–1.9% Cu and 0.17–0.37% Ni. Thus, the plant can be

Fig. 1. Photograph of *Blepharis aspera* growing in its natural environment at Selkirk, Botswana.

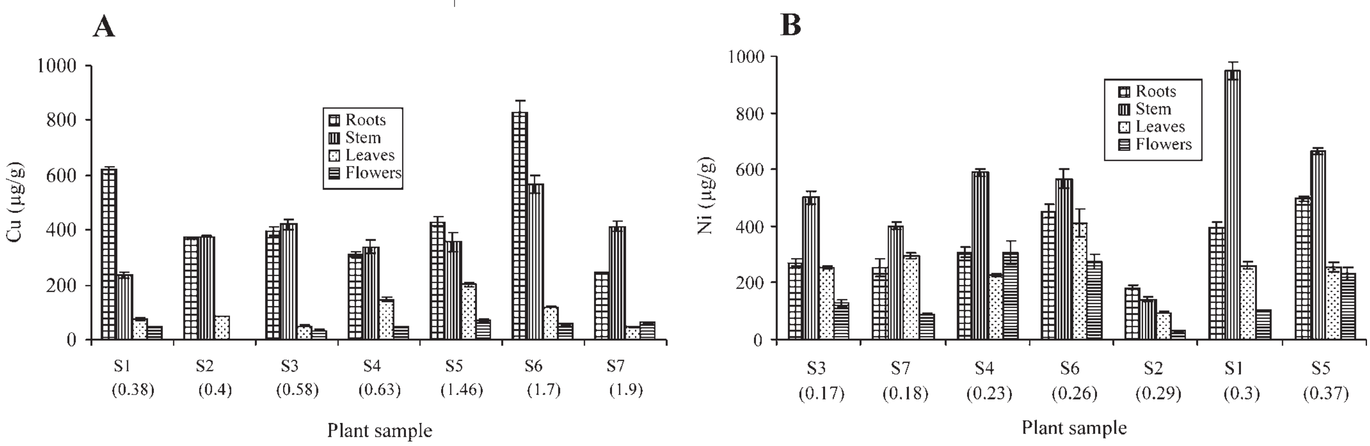

Fig. 2. Graphs of (**A**) Cu and (**B**) Ni concentrations in plant parts of *Blepharis aspera*, arranged according to increasing soil metal concentration from left to right. The soil metal concentrations (in %) are shown in brackets below the sample designation. S represents the sampling location, Selkirk (the number that follows is arbitrary). The error bars represent the standard deviation (n = 5). Note: the S2 flower was not available for Cu determination.

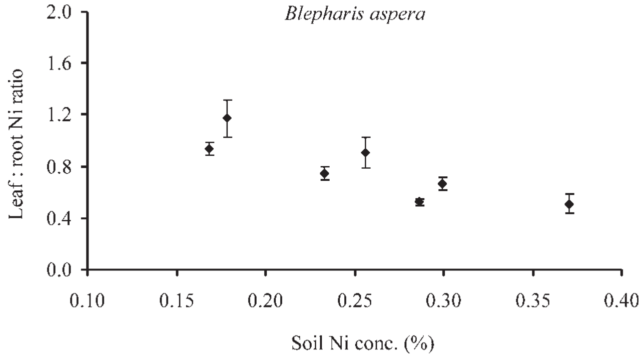

Fig. 3. Plot of leaf to root Ni concentration ratio against the metal concentration in the soil. The error bars represent the standard deviation ($n = 5$).

classified as a metallophyte. To investigate if it could be used as a Cu–Ni indicator plant, it was important to know if *B. aspera* accumulated Cu and Ni in high amounts, to establish the type of metal tolerance (exclusion or accumulation), and also to determine the leaf to soil metal concentration ratios.

Figures 2A and B show the metal concentrations in the roots, stem, leaves and flowers, for Cu and Ni, respectively, arranged according to increasing soil metal content. The plant accumulated both metals mostly in the stem or roots, and least in the flowers. The metal concentrations recorded can be seen in Fig. 2. These values are higher than the corresponding concentrations typically found in plants.[6–8]

The leaf to root ratios of copper concentration (L/R ratios) were in all cases less than 0.6 and seemed to be independent of metal concentration in the soil, whereas the Ni L/R ratio decreased with increasing metal content in the soil range tested as shown in Fig. 3. *Blepharis aspera* therefore behaved as a copper excluder in all soils investigated ($L/R < 1$), and as a nickel excluder in relatively high-Ni soils (concentrations greater than about 2.5 mg g^{-1}).[2]

The metal transfer coefficient (TC),[6,9] which is defined as the ratio of the metal concentration in the plant to the total metal concentration in the soil, was used to estimate metal uptake and transfer to the shoot. In our study, the metal concentration in the leaf was used as an estimate of the plant concentration. The TCs for *B. aspera* were in the range 0.01–0.02 for Cu and 0.1–0.2 for Ni. The Ni TCs were higher than the corresponding copper values by an order of magnitude, indicating that for the same metal concentration in the soil, Ni had higher uptake and translocation. The Cu TCs varied little with soil metal concentrations in the range 0.38–1.9%, suggesting a metal uptake and translocation that was proportional to the soil metal concentration. As such, *B. aspera* can be proposed as a Cu indicator plant for biogeochemical prospecting.

Also, the Ni TCs did not vary much. However, as the Ni concentration range of the soil was smaller (0.17–0.37%) than for Cu, more data over a wider concentration range are needed to propose *B. aspera* as a Ni indicator plant.

Our work so far has revealed that the two metallophytes, *B. aspera* and *H. candolleanum*, which grow in the same mineralized area, accumulate Cu and Ni differently in their various plant parts, implying different modes of metal tolerance. *Helichrysum candolleanum* has a tendency to take up metals and transfer them to the higher parts (leaves and flowers), which indicates accumulator behaviour,[1] whereas *B. aspera* tends to restrict most of the metal to the stem and roots, a feature of excluder behaviour. Although *B. aspera* may thus be classified as an excluder plant, it still transfers some metal to the leaves in proportion to the soil metal content, especially for Cu. This suggests that it may be used for biogeochemical prospecting, in which a constant plant: soil ratio is of particular interest[3] because it reflects the degree of mineralization in the soil. *Helichrysum candolleanum* also had relatively constant Cu and Ni TCs over a wide range of soil metal concentrations, implying metal uptake and translocation proportional to the soil concentration, and hence could act as a Cu–Ni indicator plant.[1] Of the two species, *H. candolleanum* may be a better Cu and Ni indicator for biogeochemical prospecting because of its ability to shift metals to its above-ground parts and thus can be more readily sampled in the field.[7]

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1. Nkoane B.B.M, Sawula G.M., Wibetoe G. and Lund W. (2005). Identification of Cu and Ni indicator plants from mineralised locations in Botswana. *J. Geochem. Explor.* **86**, 130–142.
2. Baker A.J.M. (1981). Accumulators and excluders – strategies in the response of plants to heavy metals. *J. Plant Nutr.* **3**, 643–654.
3. Baker A.J.M. and Brooks R.R. (1989). Terrestrial higher plants which hyperaccumulate metallic elements – a review of their distribution, ecology and phytochemistry. *Biorecovery* **1**, 81–126.
4. Van Wyk B. and Malan S. (1988). *Field Guide to the Wild Flowers of the Witwatersrand and Pretoria Region.* Struik, Cape Town.
5. The Flora of Zimbabwe: Online: http://www.zimbabweflora.co.zw
6. Adriano D.C. (2001). *Trace Elements in Terrestrial Environments: Biochemistry, Bioavailability and Risks of Metals,* 2nd edn. Springer-Verlag, New York.
7. Kabata-Pendias A. and Pendias H. (1992). *Trace Metals in Soils and Plants,* 2nd edn. CRC Press, Boca Raton, Florida.
8. Loneragan J.F. and Robson A.D. (eds). (1981). *Copper in Soils and Plants.* Academic Press, New York.
9. Henning B.J., Snyman H.G. and Aveling T.A.S. (2001). Plant–soil interactions of sludge-borne heavy metals and the effect on maize (*Zea mays* L.) seedling growth. *Water SA* **27**, 71–78.