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Identification of Cu and Ni indicator plants from mineralised locations in Botswana

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Abstract

Plant species that accumulate high levels of metals in proportion to the metal content in the soil are of considerable interest in biogeochemical and biogeobotanical prospecting. This study was aimed at investigating copper and nickel accumulation in the plants *Helichrysum candolleanum* and *Blepharis diversispina*, to assess their potential use as mineral indicators in biogeochemical prospecting. Soils and plants were collected from copper–nickel mineralised areas in Botswana. Analyses of the soils and the respective plant parts (roots, stem, leaves and flowers) were carried out using ultrasonic slurry sampling electrothermal atomic absorption spectrometry (ETAAS), which allowed rapid determination of copper and nickel in small amounts of the samples.

The metal concentration in the soil was in the range ≈ 40 μg/g–4% (w/w) for Cu and ≈ 60 μg/g–0.3% (w/w) for Ni. The concentration ranges of the elements in the plant parts were ≈ 6 μg/g–0.2% Cu and ≈ 3–210 μg/g Ni. At high soil metal content (greater than 2.5% (w/w) Cu and 0.1% (w/w) Ni), high levels of both nickel and copper were found in the shoots (leaves and flowers) of *H. candolleanum*. Concentrations as high as 0.2% (w/w) Cu were found in the leaves and flowers of *H. candolleanum*, indicating hyperaccumulation for this plant. For *B. diversispina*, the metal concentrations did not exceed 100 μg/g for any plant part, for both metals. Both plant species tolerate high concentrations of metals and should therefore be categorized as metallophytes. In order to evaluate metal translocation from the soil to the shoots, metal leaf transfer coefficients (ratio of metal concentration in the leaf to metal concentration in the soil) were calculated. Our data suggest that the two plant species have different metal uptake and transport mechanisms, which needs to be investigated further. The present work also suggests that *H. candolleanum* may be used as a copper/nickel indicator plant in biogeochemical or biogeobotanical prospecting.

Keywords: *Helichrysum candolleanum*; *Blepharis diversispina*; Copper; Nickel; Indicator plants; Metallophytes

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1. Introduction

Metal-tolerant plants have been extensively studied for various reasons, including their potential use in prospecting for minerals (Dunn et al., 1996; Brooks, 1998a) and in cleaning up or remediation of heavy metal contaminated soils (i.e., phytoremediation, phytoextraction processes) (Raskin et al., 1997; Van der Lelie et al., 2001; Vassilev et al., 2004).

Biogeochemical and biogeobotanical prospecting are some of the methods in which metal-tolerant plants are used to indicate the presence of minerals (Brooks, 1998b; Reeves and Baker, 2000; Adriano, 2001). Biogeochemical prospecting involves chemical analysis of plants, as an alternative to soil analysis, in order to detect the presence of mineralization beneath the earth surface (Brooks, 1972). For example, twigs of the black spruce (*Picea mariana*) were used to delineate uranium in Wollaston, Saskatchewan, Canada (Brooks, 1998b). In cases where the plant grows only in mineralized areas, once the plant has been identified as a good mineral indicator, just its presence can be used to identify the minerals in the soil i.e., geobotanical prospecting. For example, the 'Zambian copper flower' *Becium centraliafricanum* (*B. homblei*), has been used extensively in locating copper in the Shaba Province of Zaire (now the Democratic Republic of Congo) and the Zambian copper belt (Brooks, 1998b; Brummer and Woodward, 1999; Malaisse et al., 1999; Morrison et al., 1981).

In Botswana, biogeochemical studies have been done in the Ghanzi and Ngwako Pan areas in the late 1960s to late 1970s, in order to investigate unknown but inferred copper mineralization hidden underneath the calcrete and Kalahari sand covers (Cole and Le Roex, 1978). In the Ghanzi area, Cole and coworkers were able to use *Helicrysum leptolepis* DC (Compositae family) to indicate copper mineralization in areas of shallow overburden; while in the Ngwako Pan area, Ngamiland, the deeper rooting indicator shrubs such as the blue flowering *Ecbolium lugardae* (Acanthaceae family) were used to locate copper obscured by a thick blanket of wind-blown sand (Cole and Le Roex, 1978). At about the same time, *E. lugardae* was found at the Palaborwa and Messina copper mines (Cole and Le Roex, 1978). *H. leptolepis* has also been found in areas where copper and nickel concentration of surface soil was high, such as Selibe–Phikwe and Matsitama areas in eastern Botswana and other places in South Africa and Namibia where copper was found (Cole, 1971). Although these species were found in areas where there was copper mineralization (0.1% Cu), the copper accumulated was only slightly higher than in normal plants. Another record of biogeochemical work was in the early 1990s by Kausel in the Ngwako Pan area, who found out that the occurrence of the blue flowering species, *Monechma divaricantum*, correlated well with the occurrence of the copper bearing orebody near the surface, although the copper concentration in the plant was not higher than normal (Kausel, 1991).

In the early 1990s, work aimed at identifying plants that tolerate high copper and nickel content started at the University of Botswana (Takuwa et al., 1997), with plants from the north-east of Botswana (see Fig. 1). Survey studies conducted in our laboratories (Takuwa, 1995, Takuwa et al., 1997; Ramocha, 2002) have revealed elevated levels of copper and nickel in *Helichrysum candolleanum* H. Buek (Asteraceae family) and *Blepharis diversispina* (Nees) C. B. Clarke (Acanthaceae family) amongst other plants. Baker (1981) proposed two different strategies that metal-tolerant plants can use to cope with high levels of metals in the soils they grow in-exclusion (from the shoot) and accumulation (in the shoot). Based on these strategies, Baker (1981) suggested three types of plant–soil relationships: excluders, accumulators and indicators.

Excluders are defined as plants that restrict transport of metals to the shoot, and maintain relatively low metal concentration in the shoot over a wide range of metal concentrations in the soil. High metal accumulation may be found in the roots of excluder plants and their leaf to root metal concentration ratio is less than 1.0 (Baker, 1981; Baker and Brooks, 1989; Terry and Bañuelos, 2000). There can be another type of exclusion, whereby metals are restricted from entering the plant (Tilstone and Mcnair, 1997).

The accumulators show a tendency or ability to translocate and accumulate high levels of metal in the above-ground plant parts, from both low and high soil metal concentration levels, without any associated toxicity symptoms, i.e., their leaf to root metal concentration ratio is greater than 1.0 (Baker, 1981; Baker and Brooks, 1989; Tilstone and Mcnair, 1997; Terry and Bañuelos, 2000). For indicator