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# HYPERACCUMULATION OF NICKEL BY GEISSOIS SPECIES

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*Key words*

Accumulation Chromium Cobalt Hyperaccumulates Iron Nickel

*Summary*

Herbarium specimens of 17 species of Geissois were analysed for nickel, cobalt, chromium and iron with a view to discovering further hyperaccumulators of nickel (> 1000 μg/g on a dry mass basis) in addition to the previously recorded *G. pruinosa*. A further six hyperaccumulators were discovered, all from New Caledonia. Unlike 90% of hyperaccumulators, Geissois is in Subclass Rosidae of the Magnioliate which it shares with three other hyperaccumulators (two species of *Argophyllum* and *Pearsonia metallifera*. The work highlights the remarkable concentration of hyperaccumulators in New Caledonia.

## Introduction

Plant species capable of accumulating nickel to an inordinately high degree (> 1000 μg/g in dried vegetation) have been termed *hyperaccumulators*[2]. Such plants are confined largely to New Caledonia and include species of the genera Argophyllum[7], Geissois[5], Homalium[2], Hybanthus[2], Phyllanthus[7], Psychotria[5], and Sebertia[6]. Hyperaccumulators of nickel are of interest to phytochemists because of the very high concentrations of nickel: an element normally toxic to vegetation. They are also of interest for geobotanical and biogeochemical mineral exploration[1] because of their almost exclusive occurrence on nickel-rich rocks. Accumulation of such large quantities of nickel is also of interest to workers in the field of mineral technology, because if the low-energy processes inherent in metal uptake by plants could be emulated technologically, there might be an alternative to the existing high energy commercial processes for extraction of nickel from its ores.

A maximum of about 8000 μg/g nickel has previously been reported in leaves of the serpentine-endemic New Caledonian species *Geissois pruinosa* Brongn. et Gris. and since there are at least 19 other species in New Caledonia and the neighbouring territories of Australia, Fiji, New Hebrides and the Solomon Islands, the question arises as to whether hyperaccumulation of nickel is confined to only a single species. Discovery of additional hyperaccumulators in this genus should give stimulus to associated phytochemical, biogeochemical, and mineral technological fields.

The Cunoniaceae is a dominant family of the ultrabasic regions of New Caledonia. Of

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Table 1. List of co-operating herbaria

| Country | Herbarium |
|---|---|
| Australia | Queensland Herbarium, Indooroopilly (BRI) |
| Fiji | Fiji Herbarium, Suva (SUVA) |
| France | Muséum National d'Histoire Naturelle, Paris (P) |
| New Caledonia | Centre O.R.S.T.O.M. de Nouméa, Nouméa (NOU) |
| Switzerland | Institut für Systematische Botanik, Zürich (Z) |
| United Kingdom | British Museum, London (BM) |

the 76 species of this family found on the island, 58 are present on ultrabasic rocks and two-thirds of these are found exclusively thereon. The family is dominant on most of the different vegetation communities which comprise the highly-developed serpentine flora of New Caledonia.

The results of a survey of this nickel content of *Geissois* species of New Caledonia are presented in this paper.

## *Materials and methods*

After allowance for synonyms, 20 species of *Geissois* (11 from New Caledonia, 2 from Australia, 1 from the Solomons, 2 from New Hebrides and 4 from Fiji) are listed in *Index Kewensis* (there being no revision of the genus). At least 2 specimens of each species (except *G. Lachnocarpa*, *G. parviflora* and *G. pentaphylla*) were obtained from herbaria of the institutions listed in Table 1. The original work of Brooks *et al.*[2] showed that herbarium material was ideal for research of this kind since the analytical methods required only very small leaf samples.

A total of 132 specimens of 17 species of Geissois (including many holotypes) from six institutions were analysed as follows: Samples (av. wt. about 0.03 g *i.e.* 1 $cm^2$) were placed in 5 ml borosilicate test-tubes and ignited at 500°C in a muffle furnace. The ash in each tube was then dissolved in 1 ml of 2 *M* hydrochloric acid prepared from redistilled reagent. The solutions were analysed for chromium, cobalt, iron and nickel by atomic absorption spectrophotometry using a hydrogen continuum lamp for background correction. Samples containing inordinately high iron contents (> 500 µg/g) were assumed to be contaminated by soils and were rejected if they also contained high nickel and chromium concentrations. All data were expressed as µg/g (ppm) on a dry-mass basis. The species was the basic unit recognised and included all subspecies and varieties.

## *Results and discussion*

The analytical data are shown in Table 2. It will be noted that a further six species of New Caledonian *Geissois* (*i.e.* in addition to *G. pruinosa*) have maximum nickel concentrations of 1000 µg/g or over. These species are: *G. racemosa* (1000 µg/g); *G. magnifica* (3250 µg/g); *G. hirsuta* (4000 µg/g); *G. montana* (5740 µg/g); *G. trifoliolata* (6250 µg/g); *G. pruinosa* (13,600 µg/g); *G. intermedia* (22,900 µg/g). It is also noteworthy that two other New Caledonian species: *G. balansae* and *G. velutina* have maximum nickel levels (694 and 361 µg/g) which are considerably in excess of the 50–100 µg/g expected for 'normal' plants growing over ultrabasic substrates.

Geologically, Fiji is lacking in nickel-rich ultrabasic rocks and it is therefore not surprising that no hyperaccumulators of nickel were to be found among the 4 Fijian species. Nevertheless the 50 μg/g nickel reported for *G. imthurnii* and 42 μg/g for *G. ternata* are remarkably high in relative terms. The Fijian species were also able to accumulate cobalt relative to nickel (the Co/Ni ratio was over 1.0 in most cases) in contrast with the New Caledonian species.

The chromium content of most *Geissois* species was surprisingly high. The highest values (463 μg/g in *G. pruinosa* and 197 μg/g in *G. montana*) coincided with relatively low iron contents and do not appear to be a result of contamination by soil. Chromium is not usually available to plants. Hence concentrations exceeding 10 μg/g are unusual for 'normal' plants even when growing over ultrabasic substrates.

The presence of 7 hyperaccumulators of nickel in a single genus is only equalled by Homalium[2] (also in New Caledonia) and surpassed by Alyssum[3]. Unlike these two genera however, Geissois also has an appreciable chromium content and would thereby appear to have a tolerance to ultrabasic substrates exceeding that of most other species.

The work on Geissois highlights the relatively high abundance of hyperaccumulators of nickel in New Caledonia. To date, 14 such species (excluding Geissois) have been discovered in that island and until recent work on Alyssum, these accounted for over half of all known hyperaccumulating species. Well over 90% of hyperaccumulators (*e.g.* Alyssum, Homalium, Hybanthus and Phyllanthus) are found in Subclass Dilleniidae[4] of the Magnoliatae. Geissois (Cunoniaceae) is in Subclass Rosidae which includes three other hyperaccumulators (*Pearsonia metallifera*[8] from Rhodesia and two species of Argophyllum[7] from New Caledonia). Both Geissois and Pearsonia are unusual in that they are both able to accumulate chromium to relatively high levels (*i.e.* 400–500 μg/g), and this may be a characteristic of some hyperaccumulators in Subclass Rosidae.

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Table 2. Concentrations (μg/g dry mass) of heavy metals in *Geissois* species

| Species | Number analysed | Location | Cobalt | | Chromium | | Iron | | Nickel | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| *G. balansae* Brongn. & Gris. ex Guillaumin | 6 | New Caledonia | 15 | 1–57 | 29 | 1–150 | 135 | 23–221 | 230 | 1–684 |
| *G. benthami* F. Muell | 4 | Australia | 3 | 1–7 | 3 | 1–7 | 200 | 35–317 | 15 | 1–56 |
| *G. denhamii* Seem. | 3 | New Hebrides | 1 | – | 1 | – | 77 | 34–160 | 1 | – |
| *G. hippocastaneifolia* Guillaumin | 5 | New Caledonia | 2 | 1–7 | 1 | – | 104 | 14–183 | 5 | 1–12 |
| *G. hirsuta* Brongn. et Gris. | 10 | New Caledonia | 33 | 1–227 | 22 | 1–73 | 216 | 114–385 | 1650 | 577–4000 |
| *G. imthurnii* Turrill | 8 | Fiji | 17 | 1–43 | 2 | 1–4 | 179 | 22–667 | 14 | 1–50 |
| *G. intermedia* Vieill. ex Pampan. | 5 | New Caledonia | 16 | 1–59 | 15 | 1–59 | 62 | 26–85 | 8330 | 1-22,900 |
| *G. lachnocarpa* Maiden | | Australia | not analysed | | | | | | | |
| *G. magnifica* E. G. Baker | 2 | New Caledonia | 3 | 1–4 | 7 | 1–12 | 171 | 163–180 | 2210 | 1170–3250 |
| *G. montana* Vieill. ex Brongn. et Gris. | 8 | New Caledonia | 15 | 1–58 | 37 | 1–197 | 53 | 14–125 | 2620 | 1–5740 |
| *G. parviflora* Guillaumin | | New Hebrides | not analysed | | | | | | | |

Table 2 *(continued)*

| Species | Number analysed | Location | Cobalt | | Chromium | | Iron | | Nickel | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| *G. pentaphylla* G. T. White ex F. S. Walker | | Solomons | not analysed | | | | | | | |
| *G. polyphylla* Lecard ex Guillaumin | 5 | New Caledonia | 4 | 1–14 | 1 | – | 114 | 14–256 | 7 | 1–19 |
| *G. pruinosa* Brongn. et Gris. | 31 | New Caledonia | 30 | 1–238 | 45 | 1–463 | 154 | 40–336 | 6560 | 1490–13,600 |
| *G. racemosa* Labill | 7 | New Caledonia | 4 | 1–20 | 20 | 1–96 | 325 | 20–769 | 212 | 1–1000 |
| *G. stipularis* A. C. Smith | 4 | Fiji | 2 | 1–7 | 1 | – | 25 | 8–32 | 2 | 1–5 |
| *G. superba* Gillespie | 5 | Fiji | 1 | 1–2 | 1 | – | 73 | 1–263 | 1 | – |
| *G. ternata* A. Gray | 23 | Fiji | 16 | 1–90 | 2 | 1–6 | 62 | 6–210 | 8 | 1–42 |
| *G. trifoliolata* Guillaumin | 3 | New Caledonia | 10 | 1–32 | 40 | 12–94 | 176 | 57–312 | 3450 | 956–6250 |
| *G. velutina* Guillaumin | 3 | New Caledonia | 1 | – | 7 | 1–22 | 228 | 134–370 | 27 | 93–361 |