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NICKEL UPTAKE BY NEW CALEDONIAN SPECIES OF *PHYLLANTHUS*

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Summary

Herbarium specimens (nearly 350) of New Caledonian species of *Phyllanthus* (Euphorbiaceae) were analysed for their nickel and cobalt contents with a view to discovering new hyperaccumulators of nickel (>1000 μg/g dry mass) and to assisting in chemotaxonomic classification of this difficult genus. A total of 10 hyperaccumulators were identified and it was possible to characterise and identify a number of species from their nickel and/or cobalt contents. This was particularly true for the taxonomically difficult section *Heteroglochidion*. This work raises to 40 the number of known hyperaccumulators of nickel found in New Caledonia.

Introduction

The genus *Phyllanthus* (Euphorbiaceae) comprises over 1000 species of which about 50 are found in New Caledonia (Guillaumin, 1911, 1929, 1948). To date, there has been no recent comprehensive revision of the New Caledonian members of this genus beyond the work of Guillaumin (1948) in which he recognised 58 species spread over 10 sections. Taxonomically the genus is extremely difficult and in many cases it is hard to characterise a given species closer than at the section level.

It has been shown that chemical analysis of herbarium material can be used to assist in taxonomic problems. Brooks, McCleave, and Schofield (1977) used the cobalt content of *Nyssa* to show that all six species could be differentiated by their cobalt content alone. Analysis of herbarium material has also been used to identify hyperaccumulators of nickel (plants containing > 1000 μg/g). Much of this work was carried out in New Caledonia (Brooks et al., 1977; Jaffré et al., 1979) and resulted in the discovery of about thirty hyperaccumulators of nickel (nickel plants), mainly in the genera *Geissois*, *Homalium*, and *Xylosma*. Excessive nickel uptake by plants is of interest not only in the field of taxonomy and phytochemistry but also in the field of metallurgy. Nickel plants use a source of low energy (sunlight) to solubilise insoluble nickel from its substrate and convert it to a water-soluble organic complex (Lee et al., 1977, 1978). If such a process could be reproduced technologically, the current high-energy methods of extraction of nickel from its ores could be superseded.

Because of the significance of nickel plants in the above fields, an attempt has been made to identify as many of them as possible. Spot tests (using dimethylglyoxime) on specimens at the Nouméa Herbarium (New Caledonia) revealed the possibility of there being several hyperaccumulators in the genus *Phyllanthus*. Knowledge of the nickel content of the species would be of great use taxonomically because of the extreme difficulty of classification posed by this genus. The results of a survey of the cobalt and nickel content of New Caledonian *Phyllanthus* are summarised in this paper.

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Materials and Methods

Herbarium material of leaves of *Phyllanthus* was obtained from: Centre O.R.S.T.O.M. de Nouméa, New Caledonia (NOU); The British Museum (BM); Muséum National d'Histoire Naturelle, Paris (P). A total of nearly 350 specimens was analysed, the bulk of which came from Nouméa. The remainder included type material from the British Museum (BM). Samples (av. mass 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 analyzed for cobalt and nickel by atomic absorption spectrophotometry. Corrections for non-atomic absorption were made via a hydrogen continuum lamp. All concentration data were expressed on a dry-mass basis.

Results and Discussion

The analytical data for cobalt and nickel in *Phyllanthus* species are summarised in Table 1. Because elemental concentrations tended to be log-normally distributed (in cases where the number of specimens was great enough to establish this) the geometric means are given. The species (51) are listed under sections and include all except 8 of the taxa recognised by Guillaumin (1948). The results will now be discussed under the individual sections.

Table 1. Nickel and cobalt concentrations (μg/g dry mass) in *Phyllanthus* species from New Caledonia.

		Nickel		Cobalt	
Species	No.	G.Mean	Range	G.Mean	Range
SECTION EU-PHYLLANTHUS					
**P. chrysanthus* Baill.	3	624	240–1180	1	1–5
P. persimilis Muell.	13	114	1–403	3	1–50
P. rufidulus Muell.	6	252	87–772	2	1–9
P. simplex Retz.	5	12	7–18	1	1–1
SECTION POLYANDROGLOCHIDION					
**P. ngoyensis* Schlecht	3	8800	8240–9550	102	36–796
P. sylvincola Moore	5	159	33–772	6	1–43
P. trichopodus Guill.	7	2	1–9	1	1–1
P. umbraecolus Guill.	1	89	–	21	–
SECTION PENTAGLOCHIDION					
**P. kanalensis* Baill.	6	127	26–1090	9	2–44
SECTION ELEUTHEROGYNIUM					
P. erythrantus Guill.	1	381	–	9	–
P. induratus Moore	8	350	46–1480	5	1–24
P. longeracemosus Guill.	4	375	189–822	13	8–27
P. loranthoides Baill.	1	1	–	1	–
P. macrochorion Baill.	1	142	–	11	–
P. mareensis Guill.	4	3	1–6	1	1–3
P. salicifolius Baill.	5	15	5–60	2	1–7
P. triquetrus Moore	4	10	7–31	1	1–1
P. vespertilio (Muell.) Baill.	4	63	11–436	1	1–1
P. yahouensis Schlecht	3	56	5–696	3	1–17

SECTION PHYSOGLOCHIDION					
P. faguetii Boiv.	4	32	2–598	6	2–20
P. jaubertii Vieill.	1	428	–	1	–
P. koghiensis Baill.	4	10	4–36	1	1–2
P. platycalyx Muell.	3	184	33–442	2	1–8
SECTION GOMPHIDIUM					
P. balansaeanus Guill.	2	442	108–1820	2	1–3
P. bourgeoisii Baill.	6	2	1–7	2	1–4
P. buxoides Guill.	16	15	1–146	3	1–18
**P. cataractarum* Muell.	14	58	2–1450	6	1–95
P. caudatus Muell.	5	27	1–402	5	2–14
P. chamaecerasus Baill.	3	219	91–320	2	1–16
P. comptonii Guill.	6	144	41–320	8	1–35
P. cornutus Baill.	11	70	13–489	6	2–50
P. lifuensis Guill.	2	9	4–22	1	1–1
P. pancherianus Baill.	26	63	10–262	3	1–66
P. poumensis Guill.	13	106	3–543	3	1–39
P. pterocladus Moore	2	51	32–82	3	2–5
P. virgultiramus Däniker	2	109	32–372	12	2–71
SECTION ADENOGLOCHIDION					
P. aeneus Baill.	24	657	9–2100	8	1–39
SECTION HETEROGLOCHIDION					
P. baladensis Baill.	11	13	3–207	5	1–51
**P. casearioides* Moore	1	68	–	90	–
P. deciduiramus Däniker	4	145	4–705	5	2–14
P. francii Guill.	1	37	–	1	–
P. koumacensis Guill.	6	83	37–110	2	1–4
P. maytenifolius Moore	15	392	30–1420	13	1–148
P. montrouzieri Baill.	10	491	261–791	3	1–13
P. peltatus Guill.	5	545	161–2830	4	1–35
P. pronyensis Guill.	14	67	4–961	3	1–57
P. salacioides Moore	1	270	–	18	–
**P. serpentinus* Moore	18	13800	3890–38100	100	33–270
P. toninensis Moore	2	6	4–10	6	3–11
SECTION KIRGANELIA					
P. deplanchei Muell.	3	4	1–9	2	1–4
SECTION PARAPHYLLANTHUS					
P. urinaria L.	1	2	–	1	–

* Type material analyzed.

Section Euphyllanthus.—This section contains a previously unrecorded hyperaccumulator of nickel *(P. chrysanthus)* with a maximum of 1180 μg/g nickel associated with only 5 μg/g cobalt. Although this section is not particularly difficult for taxonomic classification, it should be possible from the nickel content to differentiate *P. simplex* (low nickel) from all other species in the section.

Section Polyandroglochidion.—This section contains another hyperaccumulator *(P. ngoyensis)* with nickel values ranging from 8240–9550 μg/g and associated high levels (36–796 μg/g) of cobalt. *P. sylvincola* is only a moderate accumulator of nickel (33–772 μg/g) and can be differentiated chemotaxonomically from *P. ngoyensis* and the non-accumulator species *P. trichopodus*. Insufficient data are available to give a verdict on *P. umbraecolus*. Five *Phyllanthus* sp. specimens in the Nouméa her-

barium with nickel values in the range <1–4 μg/g are almost certainly *P. trichopodus*.

Section Pentaglochidion.—This section contains only a single taxon *(P. kanalensis)* which is another previously-unrecorded hyperaccumulator of nickel (maximum 1090 μg/g).

Section Eleutherogynium.—This section contains yet another hyperaccumulator of nickel *(P. induratus)*. It is a difficult section taxonomically. There are insufficient data for *P. erythrantus*, *P. loranthoides*, or *P. macrochorion* and the only chemotaxonomic separation possible is the differentiation of *P. induratus* or *P. longeracemosus* from the remaining 5 non-accumulating species in the section.

Section Physoglochidion.—This section contains no hyperaccumulators and the nickel content of its four species is of no assistance in chemotaxonomic classification.

Section Gomphidium.—This section contains two hyperaccumulators of nickel *(P. balansaeanus* and *P. cataractarum)* but its constituent species are taxonomically difficult to classify. Of the 24 unclassified herbarium specimens belonging to this section at Nouméa, a probable identity could only be assigned in about 5 or 6 cases.

Section Adenoglochidion.—This section presents no taxonomic problems as it includes only a single species *(P. aeneus)* which is itself another hyperaccumulator (max 2100 μg/g) of nickel.

Section Heteroglochidion.—This section is one of the most interesting and important in the genus *Phyllanthus*, as well as one of the most difficult taxonomically. Morphological similarities make it extremely difficult to differentiate between *P. casearioides*, *P. serpentinus*, *P. maytenifolius*, and *P. salacioides*. Furthermore, it is not even certain that *P. serpentinus* and *P. maytenifolius* are not both the same species. Fig. 1 gives a representation of the nickel and cobalt contents of *Phyllanthus* species from section *Heteroglochidion*. The centre of each ellipse gives the geometric mean and the straight lines radiating from the centre give the limits of one standard deviation. From the specimens available to us (not necessarily a complete cross section), it is clear from Fig. 1, that *P. serpentinus*, *P. casearioides*, and *P. maytenifolius* are entirely differentiated from each other by their nickel and cobalt contents. *P. salacioides* (only one specimen was available) is not differentiated from *P. maytenifolius*.

At the O.R.S.T.O.M. herbarium there are eight specimens of *Phyllanthus* provisionally classified as "*P. casearioides*." These specimens had nickel contents ranging from 12500–36100 μg/g and cobalt contents in the range 33–166 μg/g. The type specimen (BM) however, contained only 68 μg/g nickel and 90 μg/g cobalt. This leads to the possibility that all eight "*P. casearioides*" specimens are in fact another species, probably *P. serpentinus*. There is other evidence to support this postulate. The specimens of "*P. casearioides*" were all collected in the same general area as *P. serpentinus* (Poum-Tiebaghi-Koumac) whereas the type of *P. casearioides* was collected from an area (Tonine) well removed from the above localities. A further piece of supportive evidence is furnished by the high mean cobalt contents (60 and 114 μg/g) for "*P. casearioides*" and *P. serpentinus*, which translate to 90 μg/g if both groups are considered to be *P. serpentinus*. For the above reasons we have now classified "*P. casearioides*" as *P. serpentinus* in Table 1 and Fig. 1. The true *P. casearioides* is probably relatively rare (being represented only by the type) and is apparently not a hyperaccumulator of nickel.

There are apparently 3 hyperaccumulators of nickel in section *Heteroglochidion*. Two of these *(P. serpentinus* and *P. peltatus)* have not previously been recorded as having this capability, but one of us (Jaffré, 1977) has already observed hyperaccumulation of nickel by *P. maytenifolius*.

Section Kirganelia.—This section contains only *P. deplanchei* which is a non-accumulator of nickel.

Section Paraphyllanthus.—This section contains only *P. urinaria*, a non-accumulator of nickel.

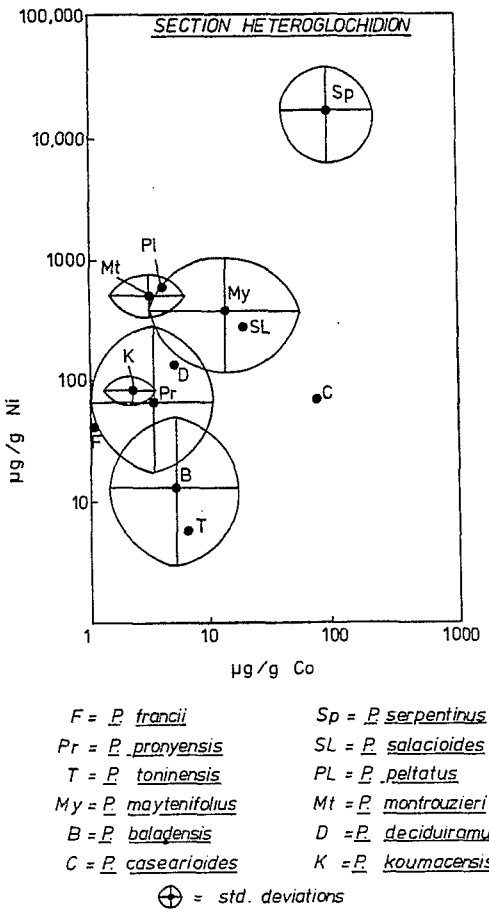

Fig. 1. The nickel and cobalt content of *Phyllanthus* species from section *Heteroglochidion*. Solid circles show geometric means and the radiating straight lines show the standard deviation range.

General Discussion and Conclusions

It is concluded that the nickel and cobalt contents of New Caledonian species of *Phyllanthus* may be used in some cases as an aid to taxonomic classification. This is particularly true of section *Heteroglochidion* which presents many problems of identification.

In this work we have recognized 10 hyperaccumulators of nickel among the 51 species studied. This is among the greatest number of hyperaccumulators yet found in any worldwide genus apart from *Alyssum* and is the greatest number found for any genus in New Caledonia except for *Xylosma* (Flacourtiaceae) which contains the same number (Jaffré et al., 1979). Like so many of the other hyperaccumulators of New Caledonia, *Phyllanthus* belongs to a primitive family (Euphorbiaceae) with an advancement index (Sporne, 1969) of only 30. A link between nickel hyperaccumulation and primitive character has already been suggested by Jaffré et al. (1979) for the Flacourtiaceae (Advancement index 22). The present work seems to confirm the same trend and also extends to 40 the number of hyperaccumulators found in the

flora of New Caledonia. The New Caledonian species constitute one of the two major groups of nickel plants known at present, the other group consisting of 45 species of *Alyssum* (Brooks et al., 1979) and several other species from the Cruciferae of Europe and Western Asia (Reeves and Brooks, unpublished work).

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