

[10.1071/BT23070](https://doi.org/10.1071/BT23070)

*Australian Journal of Botany*

### **Supplementary Material**

#### **The extent and applications of metal accumulation and hyperaccumulation in Philippine plants**

*Sarah Duddigan<sup>A,\*</sup>, Marilyn O. Quimado<sup>B</sup>, Edwino S. Fernando<sup>B</sup>, and Mark Tibbett<sup>A</sup>*

<sup>A</sup>Department of Sustainable Land Management, Centre for Agri-Environmental Research and Soil Research Centre, School of Agriculture, Policy and Development, University of Reading, Reading, Berkshire, UK.

<sup>B</sup>Department of Forest Biological Sciences, College of Forestry and Natural Resources, The University of the Philippines – Los Baños, Los Baños, Laguna, Philippines.

\*Correspondence to: Sarah Duddigan Department of Sustainable Land Management, Centre for Agri-Environmental Research and Soil Research Centre, School of Agriculture, Policy and Development, University of Reading, Reading, Berkshire, UK Email: [s.duddigan@reading.ac.uk](mailto:s.duddigan@reading.ac.uk)

## Supplementary information

Table S1 – Observations obtained from the literature

<b>Plant families reported</b>	<b>Metals analysed</b>	<b>Number of observations</b>	<b>Reference</b>
Nephrolepidaceae; Poaceae	As; Cu	3	(Ancheta et al., 2020)
Araucariaceae; Calophyllaceae; Elaeocarpaceae; Escalloniaceae; Goodeniaceae; Podocarpaceae; Sapotaceae	Cr; Cu; Fe; Mg; Ni	35	(Aribal et al., 2016)
Dichapetalaceae; Meliaceae; Ochnaceae; Phyllanthaceae	Ni, Zn	54	(Baker et al., 1992)
Blechnaceae; Casuarinaceae; Dennstaedtiaceae; Drynariaceae; Ebenaceae; Ericaceae; Euphorbiaceae; Fabaceae; Fabaceae-Mimosoideae; Flagellariaceae; Gleicheniaceae; Lycopodiaceae; Lygodiaceae; Malvaceae-Grewioideae; Melastomataceae; Meliaceae; Menispermaceae; Myrtaceae; Nepenthaceae; Orchidaceae; Orchidaceae-Epidendroideae; Poaceae; Rubiaceae; Rutaceae	Ni	31	(Bayas et al., 2018)
Violaceae	Ni	1	(Brooks and Wither, 1977)
Flacourtiaceae	Ni	2	Brooks et al (1977)
Hypericaceae; Pteridaceae; Rubiaceae; Thelypteridaceae	Al; Cd; Co; Cr; Cu; Fe; Mg; Mn; Ni; Pb; Zn	77	(Castañares and Lojka, 2020)
Apocynaceae; Cunoniaceae; Dennstaedtiaceae; Gleicheniaceae; Nephrolepidaceae; Pteridaceae; Sapotaceae		Cu; Fe 7	(Claveria et al., 2010)
Pteridaceae		As 3	(Claveria et al., 2019a)
Dennstaedtiaceae; Gleicheniaceae; Melastomataceae; Nephrolepidaceae; Pinaceae; Poaceae; Pteridaceae	As; Cu	21	(Claveria et al., 2019b)
Blechnaceae; Cyatheaceae; Dennstaedtiaceae; Dipteridaceae; Gleicheniaceae; Lindsaeaceae; Nephrolepidaceae; Pteridaceae; Thelypteridaceae	As; Co; Cr; Cu; Fe; Ni	45	(Claveria et al., 2020)
Cyperaceae; Nephrolepidaceae; Pteridaceae; Typhaceae		Cu 6	(de la Torre et al., 2016)

Anacardaceae; Annonaceae; Calophyllaceae; Chrysobalanaceae; Combretaceae; Dilleniaceae; Ebenaceae; Fabaceae; Flacortaceae; Goodeniaceae; Lauraceae; Myrsinaceae; Myrtaceae; Ochnaceae; Phyllanthaceae; Pinaceae; Rubiaceae; Sapotaceae; Verbenaceae	Co; Cr; Cu; Ni	107	(Fernando et al., 2013)
Violaceae	Co; Cu; Ni	6	(Fernando et al., 2014)
Ochnaceae	Ni	13	(Fernando et al., 2020)
Phyllanthaceae	Ni	1	(Gotera et al., 2014)
Phyllanthaceae	Ni	1	(Gotera et al., 2020)
Phyllanthaceae	Ni	1	(Hoffmann et al., 2003)
Melastomataceae	Al	1	Proctor et al (2000)
Phyllanthaceae	Co; Cu; Ni	18	(Quimado et al., 2015)
Compositae	As; Cu; Pd; Zn	4	(Sanqui et al., 2020)
Araceae; Melastomataceae; Myrtaceae	Ni	3	(Susaya et al., 2010)

## **References**

- Ancheta, M.H., Quimado, M.O., Tiburan Jr, C.L., Doronila, A., Fernando, E.S., 2020. Copper and arsenic accumulation of *Pityrogramma calomelanos*, *Nephrolepis biserrata*, and *Cynodon dactylon* in Cu- and Au-mine tailings. *Journal of Degraded and Mining Lands Management* 7, 2201–2208.
- Aribal, L.G., Marin, R.A., Miras, N.A.P., 2016. The metallophytes in the ultramafic soil of Mt. Kiamo in Malaybalay, Bukidnon, Philippines. *J Biodivers Environ Sci* 8, 142–150.
- Baker, A.J.M., Proctor, J., van Balgooy, M.M.J., 1992. Hyperaccumulation of nickel by the ultramafic flora of Palawan, Republic of the Philippines. In: Proctor, J., Baker, A.J.M., Reeves, R.D. (Eds.), *Vegetation of Ultramafic (Serpentine) Soils*. Intercept Ltd., Andover, UK, pp. 291–304.
- Bayas, Q.E.B., Salvador, S.A.S.J., Ragragio, E.M., Obico, J.J.A., 2018. Taxonomic survey of nickel hyperaccumulating plants in a mining site on Luzon Island, Philippines. *Philipp J Syst Biol* 12, 103–108.
- Brooks, R.R., Wither, E.D., 1977. Nickel accumulation by *rinorea bengalensis* (Wall.) O.K. *J Geochem Explor* 7, 295–300.

- Castañares, E., Lojka, B., 2020. Potential hyperaccumulator plants for sustainable environment in tropical habitats Potential hyperaccumulator plants for sustainable environment in tropical habitats. *Earth and Environmental Science* 528, 1–10.
- Claveria, R.J.R., Perez, T.R., Apuan, M.J.B., Apuan, D.A., Perez, R.E.C., 2019a. *Pteris melanocaulon* Fee is an As hyperaccumulator. *Chemosphere* 236, 1–5.
- Claveria, R.J.R., Perez, T.R., Navarrete, I.A., Perez, R.E.C., Lim, B.C.C., 2020. The identification of heavy metal accumulator ferns in abandoned mines in the Philippines with applications to mine rehabilitation and metal recovery. *Journal of Sustainable Mining* 19, 46–57.
- Claveria, R.J.R., Perez, T.R., Perez, R.E.C., Algo, J.L.C., Robles, P.Q., 2019b. The identification of indigenous Cu and As metallophytes in the Lepanto Cu-Au Mine, Luzon, Philippines. *Environ Monit Assess* 191, 1–15.
- Claveria, R.R., de los Santos, C.Y., Teodoro, K.B., Rellosa, M.A., Valera, N.S., 2010. The identification of metallophytes in the Fe and Cu enriched environments of Brookes Point, Palawan and Mankayan, Benguet and their implications to phytoremediation. *Sci Diliman* 21, 1–12.
- de la Torre, J.B.B., Claveria, R.J.R., Perez, R.E.C., Perez, T.R., Doronila, A.I., 2016. Copper uptake by *Pteris melanocaulon* Fée from a Copper-Gold mine in Surigao del Norte, Philippines. *Int J Phytoremediation* 18, 435–441.
- Fernando, E.S., Celadiña, D.A., Tandang, D.N., Lillo, E.P., Quimado, M.O., 2020. *Brackenridgea* (Ochnaceae) in the Philippines, with notes on foliar nickel hyperaccumulation in the genus. *Gardens' Bulletin Singapore* 72, 255–273.
- Fernando, E.S., Quimado, M.O., Doronila, A.I., 2014. *Rinorea niccolifera* (Violaceae), a new, nickel-hyperaccumulating species from Luzon Island, Philippines. *PhytoKeys* 37, 1–13.
- Fernando, E.S., Quimado, M.O., Trinidad, L.C., Doronila, A.I., 2013. The potential use of indigenous nickel hyperaccumulators for small-scale mining in The Philippines. *Journal of Degraded and Mining Lands Management* 1, 21–26.
- Gotera, K.C., Doronila, A.I., Claveria, R.J.R., Perez, T.R., Unson, J.R.S., Peñaranda, M.C.R., Sebastian, M.B., Medina, J.C.S., 2014. *Breynia cernua* (Poir.) Müll.Arg. (Phyllanthaceae) is a hyperaccumulator of nickel. *Asia Life Sci* 23, 231–241.
- Gotera, K.M.C., Claveria, R.J.R., Doronila, A.I., Perez, T.R., 2020. Localization of nickel in the hyperaccumulator plant *Breynia cernua* (Poir.) Mull.Arg. discovered in the nickeliferous laterites of Zambales, the Philippines. *Int J Phytoremediation* 22, 127–133.
- Hoffmann, P., Baker, A.J.M., Madulid, D.A., Proctor, J., 2003. *Phyllanthus balgooyi* (Euphorbiaceae S.L.), a

new nickel-hyperaccumulating species from Palawan and Sabah. *Blumea* 48, 193–199.

Quimado, M.O., Fernando, E.S., Trinidad, L.C., Doronila, A., 2015. Nickel-hyperaccumulating species of *Phyllanthus* (Phyllanthaceae) from the Philippines. *Aust J Bot* 63, 103–110.

Sanqui, E.E.M., Claveria, R.J.R., Perez, T.R., 2020. Assessment of *Alternanthera sessilis* and *Aster philippinensis* as excluders in a small-scale Cu–Au processing site at Kias, Benguet, Philippines. *Environ Monit Assess* 192, 1–14.

Susaya, J.P., Victor, K.K., Chen, Z., Navarrete, I., 2010. Quantifying nickel in soils and plants in an ultramafic area in Philippines. *Environ Monit Assess* 167, 505–514.