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SPECIAL FEATURE PREFACE

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Ultramafic Ecology: Proceedings of the 10th International Conference on Serpentine Ecology

Recent advances in the study of serpentine plants and ecosystems: Perspectives from the 10th International Conference on Serpentine Ecology, France

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Abstract
The 10th International Conference on Serpentine Ecology was held in Nancy, France on 12–16 June, 2023. As a major international scientific forum in the field of serpentine (ultramafic) ecology, this conference brings together botanists, zoologists, microbiologists, physiologists, geneticists, geologists, soil scientists, and other applied specialists studying the ecology of ultramafic rocks and soil. A notable aspect of these meetings is the multidisciplinary nature of research on ultramafic biota, including diversity, ecology, evolution, physiology, and applied research in phytotechnologies and conservation. The main goals of the conference were to create a platform for the exchange of ideas and experiences and to promote scientific dialogue among scientists from numerous fields who share expertise in the study of ultramafic habitats worldwide. In this Special Issue we present the major topics and provide some highlights of the contributions to the 10th International Conference on Serpentine Ecology.

KEYWORDS
hyperaccumulator, International Conference on Serpentine Ecology, metallophyte, phytomining, ultramafic

1 | INTRODUCTION

Since the first conference in 1991 in Davis (California, USA), the International Conference on Serpentine Ecology (ICSE) has been growing as a multidisciplinary group of scientists who study and aid in the conservation of serpentine biota and their ecosystems. Serpentine (and other ultramafic) soils create a suite of environmental challenges for organisms (Rajakaruna & Boyd, 2014). As a type of harsh environment, serpentine habitats create globally unique ecosystems that offer excellent opportunities to explore many aspects of science (Harrison & Rajakaruna, 2011; Rajakaruna et al., 2014). The collective scientific expertise of participants in these conferences is broad, ranging from soil science to evolutionary ecology and conservation to applied agronomy. Each conference has been held in an ultramafic region with outstanding biodiversity: California, USA in 1991 (Baker et al., 1992), New Caledonia in 1995 (Jaffré et al., 1997), South Africa in 1999 (Balkwill, 2001), Cuba in 2003 (Boyd et al., 2004), Italy in 2006 (Chiarucci & Baker, 2007), Maine, USA and Québec, Canada in 2008 (Rajakaruna & Boyd, 2009), Portugal in 2011 (with five articles that appeared in the journal *Plant Ecology and Diversity*), Malaysia in 2014 (van der Ent et al., 2015), and Albania in 2017 (Echevarria et al., 2018). The 10th ICSE was held in France on 12–16 June, 2023, 6 years after the previous edition, and hosted 126 delegates from 29 countries. The conference was hosted at the Université de Lorraine with a Mid-Conference Tour to ultramafic sites in the Vosges Mountains and a Post-Conference Tour to Valle d'Aosta in Italy (Figure 1).

2 | THIS SPECIAL ISSUE OF *ECOLOGICAL RESEARCH*

The 16 articles published in this Special Issue represent a sampling of ongoing research activities worldwide on ultramafic ecosystems and give a broad account of the sessions that were held during the conference. The Special Issue starts with a personal account from Reeves (2024) who provides a travelogue of his research around the world on hyperaccumulator plants. The term "hyperaccumulator" was first coined in the title of the classical 1976 paper (Jaffré et al., 1976) on *Pycnandra* (formerly *Sebertia*) *acuminata*, which instigated a long and productive career in searching for these unusual plants around the world. The article by Pavlova et al. (2024) describes the holoparasite *Cuscuta planiflora* parasitizing the Ni hyperaccumulator *Odontarrhena* (formerly *Alyssum*) *muralis* in Bulgaria and shows that element transfer from host to parasite appeared to be element-specific and, after infection, Ni concentrations in all organs and biomass of hosts were reduced. Infection by *Cuscuta planiflora* could be a potential threat to the use of *O. muralis* for Ni agromining. New hyperaccumulators continue to be discovered, especially through the use of X-ray fluorescence scanning of

FIGURE 1 Group photo of the delegates of the 10th International Conference on Serpentine Ecology during the Mid-Conference Tour in the Vosges Mountains in France.

herbarium collections. Jakovljević et al. (2024) scanned 794 specimens of the genus *Noccaea* (formerly *Thlaspi*, well-known to consist of numerous hyperaccumulators) at the National Museum of Natural History in Paris and report on Ni hyperaccumulation in 21 taxa and Zn hyperaccumulation in 23 taxa, including several novelties. Their results confirm the suitability of this technology to discover new hyperaccumulator species worldwide and should assist in global efforts to develop a database for hyperaccumulators (Reeves et al., 2017). The article by Kyrkas et al. (2024) reports on the Ni hyperaccumulator *Bornmuellera emarginata* from Greece and shows that it can effectively grow under shaded conditions, which makes it useful for Ni phytomining under photovoltaic panels and thus may allow for multiple economic uses of the same plot of serpentine land. In a companion paper Kyrkas et al. (2024) report on propagation methods for a related species, *Bornmuellera tymphaea*, showing that vegetative propagation is highly efficient. The article by Selvi et al. (2024) reports on the invasive tree *Ailanthus altissima* which can cope with the severe anomalies of ultramafic soils in the Mediterranean region and presents a major threat to native ultramafic vegetation. Inoue et al. (2024) studied a rare species (*Saussurea ochiaiana*) from Japan and showed that habitat conditions suitable for the regeneration of this species are decreasing because of climate change and the depopulation of rural communities, implying that urgent conservation strategies are needed. Mincey and Boyd (2024) report on root foraging by the Ni hyperaccumulator *Streptanthus polygaloides* from the United States and found that it exhibited positive root foraging responses which they termed "nickelophilic root foraging." Their findings suggest that Ni hyperaccumulation has adaptive value, as opposed to the nonadaptive "inadvertent uptake" hypothesis that was listed by Boyd and Martens (1992) as a potential explanation for hyperaccumulation in a seminal paper published in the proceedings of the 1st ICSE (held in Davis, California, USA) and updated by Boyd (2014). Sherri et al. (2024) investigated the effect of polycyclic aromatic hydrocarbons and trace elements on antioxidant response and phytoextraction efficiency in *Noccaea caerulescens*. The results showed a reduction of growth parameters, together with upregulation of antioxidant enzymes and compounds as well as limitations of nutrient uptake and metal extraction. Filis et al. (2024) studied the Northern Pindus mountains in Greece where large ultramafic outcrops host many Ni hyperaccumulator plant species and report on floristic composition and ecology of plant communities of this area. They recorded a total of 22 plant taxa endemic to Greece including Ni hyperaccumulator species. Pérez-Latorre et al. (2024) created an updated checklist of serpentinophytes of the southern Iberian Peninsula and performed a range of analyses showing that the highest richness of serpentinophytes was in the main outcrop of Bermeja, followed by smaller outcrops of Alpujata, Aguas, and Guadalhorce Valley. Durand et al. (2024) tested different sustainable solutions for optimizing Ni phytoextraction using *Odontarrhena chalcidica*, showing that biostimulants may be a promising way of improving Ni concentration in shoots and plant biomass production. However, artificial exudates and mineral fertilizer did not have a positive effect on Ni phytoextraction, whilst the biodegradable chelator had no significant effect either. Jakovljević et al. (2024) reported on elemental distribution in inflorescences of the hyperaccumulators *Noccaea praecox* and *N. caerulescens* using synchrotron micro-X-ray fluorescence (μXRF). Results showed that Ni and Zn in flowers of *N. praecox* are mainly distributed in receptacle, ovary, and anthers, but in *N. caerulescens* the greatest accumulation occurs in receptacle and ovary, especially in the walls (i.e., pericarp). High Ni and Zn concentrations in flowers suggest that possible negative effects on fertility and pollinator species may occur, supporting the "elemental filter" hypothesis of Meindl and Ashman (2015). Mohtadi and Schat (2024) reported on uptake and translocation of Ni and Zn in three Brassicaceae species (*Lobularia maritima*, *Aurinia saxatilis*, and *Odontarrhena corsica*) grown in hydroponic conditions. Results showed that *O. corsica* accumulated more Ni than *L. maritima* and *A. saxatilis*, which are both non-hyperaccumulators. Mišljenović et al. (2024) investigated tissue-level elemental distribution in the Ni hyperaccumulator *O. muralis* using synchrotron μXRF and showed that Ni mainly occurred in epidermal tissue and at the base of trichomes, confirming earlier findings (Broadhurst et al., 2004) and adding physiological knowledge of this metal crop species. Quintela Sabaris et al. (2024) tested vermicomposting using earthworms on biomass of the Ni hyperaccumulator *Bornmuellera emarginata*, which is a metal crop used in phytomining. Due to earthworm activity, Ni was diluted in the vermicompost, suggesting that this approach is not useful for phytomining, but it might open up the use of vermicomposted hyperaccumulator biomass as an organic amendment for Ni-deficient crops.

A second Special Issue is currently in production in this journal which will contain additional papers on research presented at the 10th ICSE, including those from parts of the world where investigations of serpentine ecosystems and hyperaccumulator plants have only recently begun.

3 | CONCLUSIONS AND OUTLOOK

The international scientific community studying serpentine ecology is thriving, as attested by the over 100 poster and oral presentations made during the 10th ICSE, and the sampling of research included in this Special Issue. New exciting discoveries continue to be made, especially in biodiversity-rich areas in southeast Asia and Central and South America. We would like to pay special tribute to professors Roger Reeves, Alan Baker, and Jean Louis Morel, whose foundational work on metallophytes, hyperaccumulator plants, and phytotechnologies remains relevant and continues to inspire new research. Their active participation in these serpentine conferences is always much appreciated by the delegates. The next conference, the 11th ICSE, will be held in Kyoto, Japan in 2025 and we look forward to welcoming delegates there and learning about recent advances and developments in the field!

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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