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Pb accumulation in spores of arbuscular mycorrhizal fungi

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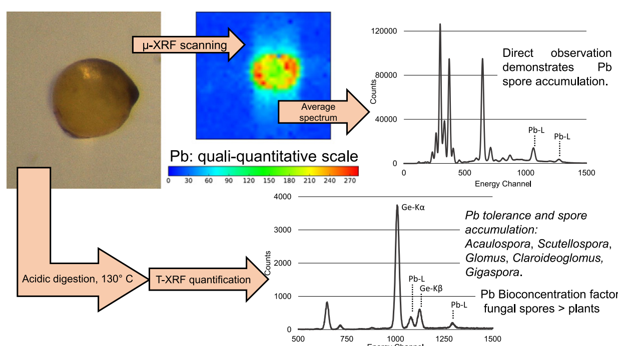
HIGHLIGHTS

- A Pb tolerant and accumulator AMF community was identified in polluted soils.
- X-Ray fluorescence was adequate for analyzing Pb accumulation in AMF spores.
- Pb accumulation in spores was directly observed in two Gigasporaceae species.

GRAPHICAL ABSTRACT



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ABSTRACT

Heavy metal (HM) pollution of soils is one of the most important and unsolved environmental problems affecting the world, with alternative solutions currently being investigated through different approaches. Arbuscular mycorrhizal fungi (AMF) are soil inhabitants that form symbiotic relationships with plants. This alleviates HM toxicity in the host plant, thereby enhancing tolerance. However, the few investigations that have addressed the presence of metals in the fungus structures were performed under experimental conditions, with there being no results reported for Pb. The current study represents a first approximation concerning the capability of spores to accumulate Pb in the AMF community present in a Pb polluted soil under field conditions. Micro X-ray fluorescence was utilized to obtain a direct observation of Pb in spores, and the innovation of total reflection X-ray fluorescence was applied to obtain Pb quantification in spores.
The AMF community included species of *Ambisporaceae*, *Archaeosporaceae*, *Gigasporacea*, *Glomeraceae and Paraglomeraceae*, and was tolerant to high Pb concentrations in soil. Pb accumulation in AMF spores was demonstrated at the community level and corroborated by direct observation of the most abundant spores, which belonged to the Gigasporaceae group. Spore Pb accumulation is possibly dependent on the AMF and host plant species.

1. Introduction

Soil contamination with heavy metals (HM) affects the ecosystems due to toxicity and leads to bioaccumulation in diverse organisms

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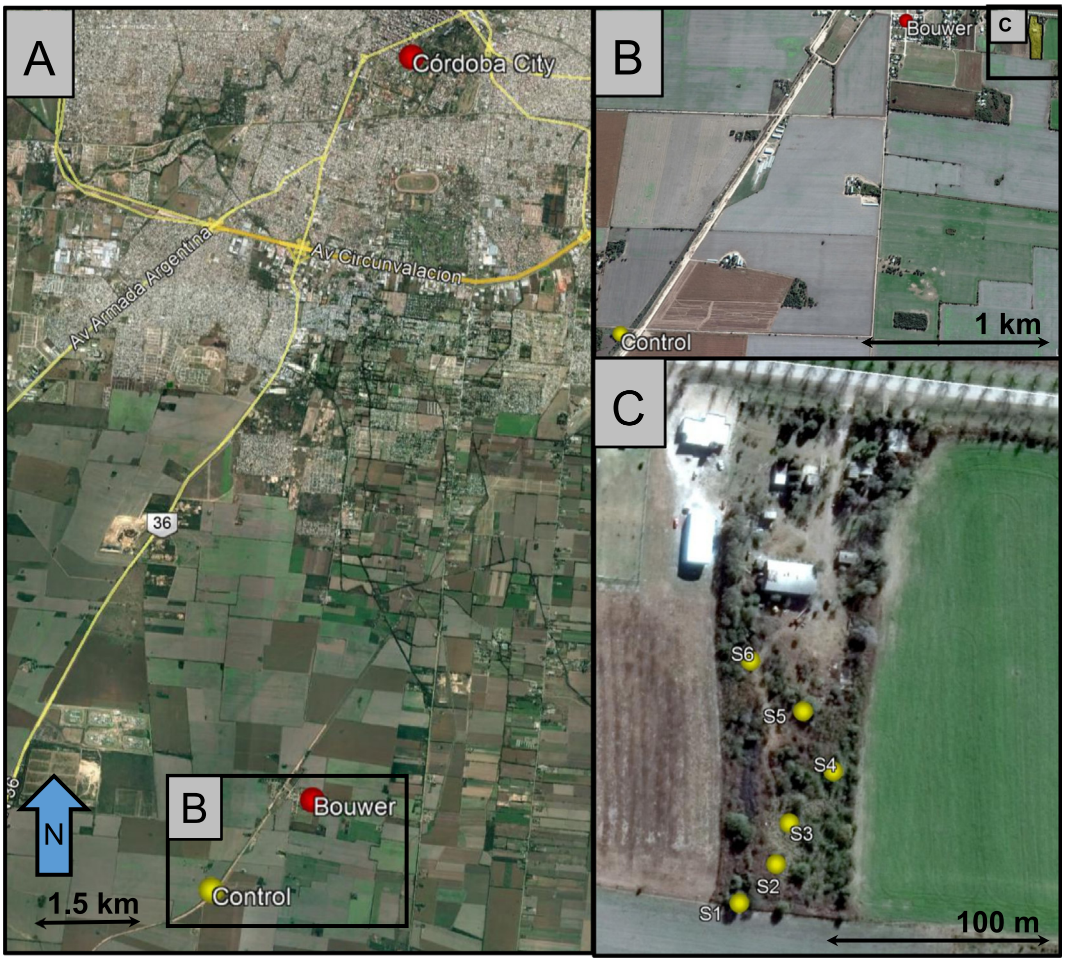

Fig. 1. Rhizosphere soil sampling area in the surroundings of a lead smelter plant located at Bouwer, Córdoba (Argentina).

(Angelova et al., 2004). Pb, in particular, is widely distributed in the environment with exposure producing adverse effects on human health (ATSDR, 2007; García-Lestón et al., 2012).

Soil is also a principal HM sink, with these pollutants being accumulated over time as they are not degradable. Consequently, their remediation requires stable contaminant removal or at least long term immobilization (Jadia and Fulekar, 2009). Conventional methods of soil remediation (excavation, pump and treat, addition of reactants, incineration, vitrification or transportation to dump sites) are expensive, destroy the soil's ability to be used as a productive resource and involve high energy consumption (Aboulroos et al., 2006; Alkorta et al., 2004; Khan and Doty, 2011).

Table 1
Soil physico-chemical parameters and Pb concentration (exchangeable and total fractions) at the sampling area.

Parameter	Sites						
	Control	S1	S2	S3	S4	S5	S6
Physico-chemical parameters							
pH	7.66	7.23	7.43	6.19	6.38	6.3	6.74
Conductivity ($ms \cdot cm^{-1}$)	0.326	0.466	0.239	0.548	0.278	0.231	0.151
Organic matter (%)	2.60	3.67	4.57	7.12	6.76	6.94	4.1
Carbon (%)	1.51	2.13	2.65	4.13	3.92	4.03	2.38
Total Nitrogen (%)	0.148	0.199	0.274	0.399	0.378	0.391	0.237
Carbon/nitrogen ratio	10.19	10.70	9.67	10.35	10.37	10.3	10.03
Extractable phosphorus ($\mu g \cdot g^{-1}$)	69.47	78.10	67.14	49.03	77.57	86.63	14.39
Exchangeable potassium ($\mu g \cdot g^{-1}$)	466.39	536.75	789.13	773.72	480.32	638.23	551.05
Pb pollution characterization							
Total ($\mu g\ g^{-1}$)	14 ± 1	365 ± 23	965 ± 56	89 ± 6	544 ± 33	2938 ± 150	16,186 ± 686
Exchangeable fraction ($\mu g\ g^{-1}$)	0.8 ± 0.3	14 ± 2	92 ± 8	3.7 ± 0.8	29 ± 3	430 ± 23	6556 ± 158
Exchangeable fraction (% of total Pb)	5 ± 1	4 ± 1	10 ± 1	4 ± 1	5 ± 1	15 ± 1	41 ± 2

pH, conductivity and exchangeable potassium were determined according to Jackson and Beltrán (1964), organic matter and carbon were determined according to Walkley and Black (1934), total nitrogen was determined according to Bremner et al. (1996), and extractable phosphorus was determined according to Bray and Kurtz (1945). The exchangeable Pb fraction was extracted with 1 M $MgCl_2$ pH 7, and the total fraction was extracted with pure HNO_3. Results are expressed relative to dry weight.