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SEED-BASED COMPROMISES AND ADAPTATIONS IN DROUGHT-RESISTANT PLANTS FACING EXTREME METAL CONTAMINATION

Kamila Murawska-Włodarczyk, Antony van der Ent, Tomasz Włodarczyk, Aneta Słomka, Wojciech J. Przybyłowicz, Jolanta Mesjasz-Przybyłowicz, Raina M. Maier, Alicja Babst-Kostecka



MINE TAILINGS FACILITY IN ARIZONA

2010



2012



2022



INTRODUCTION

Industrial and mining activities have left millions of sites with soil metal levels exceeding safe standards, leaving these areas unsuitable for reuse or habitation. Mine tailings often present challenges such as acidic conditions, poor nutrients, and low microbial life, which can be toxic to most plants.

PHYTOREMEDIATION technologies, which use metal-tolerant or metal-accumulating plants **stabilize, transform or extract metal(loid)s from contaminated waste materials**, have risen in popularity in the industrial sector.

To ensure the efficiency of phytoremediation, a thorough understanding of physiological and biochemical processes underlying **plant adaptation to environmental stress** is essential.

EXTREME WASTE, THRIVING LIFE

The Iron King–Humboldt Smelter, located in Dewey-Humboldt, AZ, USA, is an area heavily contaminated with As, Pb, Zn and Fe. Due to the high level of contamination, this site has been classified as a Superfund site, indicating a federal recognition of the threat it poses to public health and the environment.

In 2010, the University of Arizona launched a field study at the site, investigating direct planting in compost-amended tailings (Gil-Loaiza et al. 2016). Initially, there was promising plant establishment and growth, but eventually, the vegetation experienced a decline. Importantly, an astonishing outcome emerged after 13 years: a few species, including the resilient *Atriplex lentiformis*, managed to survive in this challenging and inhospitable environment.

METHODS & EXPERIMENTAL DESIGN

We compared metal accumulation strategies in reproductive plant parts between populations from polluted and non-polluted regions. To visualize the distribution of micro- and macronutrients within the seeds, we employed Synchrotron X-ray Fluorescence Microscopy (XFM) and 3D tomography. We identified and studied six regions of interest (ROI) based on visible seed morphological structures.

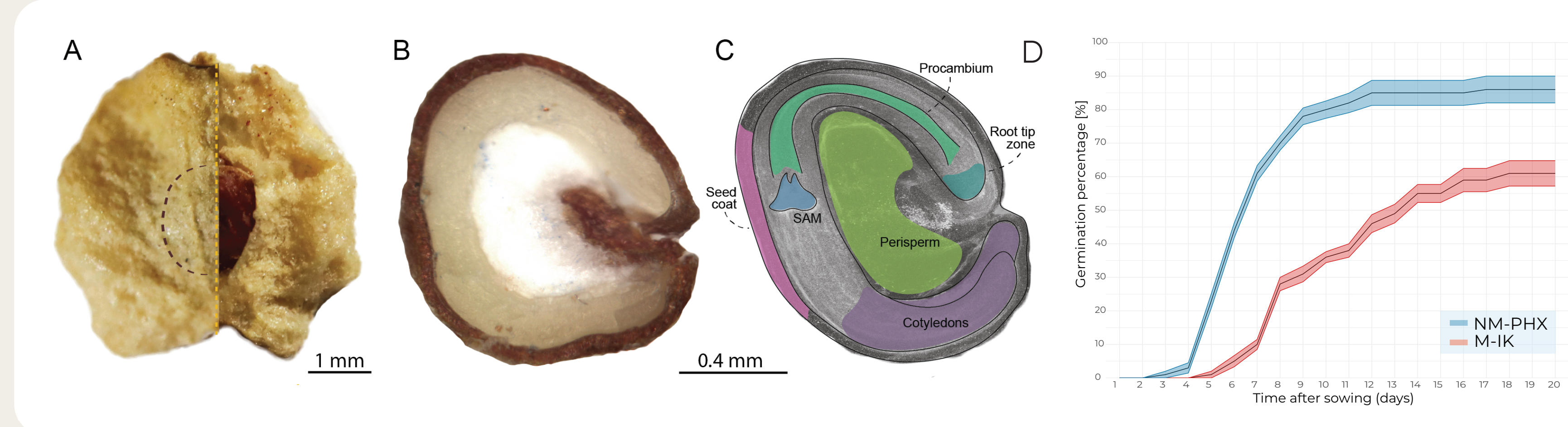


Fig. 1. Photograph of the achene of *Atriplex lentiformis* with seed (A); longitudinal section of seed (B), and schematic representation of the six seed structures (C) used in the interpretation of XFM images. (D) Mean cumulative germination percentage over time for both plant accessions.

RESULTS

- The study uncovered **striking differences in the levels and distribution of macro- and micronutrients within the seeds** of *A. lentiformis*, comparing those from metal-contaminated (metallicolous) versus control (non-metallicolous) environments.
- Particularly interesting were **Zn hotspots**, found exclusively in the seeds of the metallicolous population.
- In contrast to Zn, the translocation of **other elements** - such as Fe, As, and Pb - into the inner seed structures was limited. These elements were predominantly **stored in the seed covering tissue**, suggesting that this structure **acts as a sink and prevents excessive accumulation** of potentially toxic metal(loid)s within the seed.

CAN PLANTS HELP TO MITIGATE METAL POLLUTION IN ARID ECOSYSTEM? SURE!

...BUT HOW DOES METAL TOXICITY AT POST-MINING SITES IMPACT REPRODUCTIVE STRATEGIES OF PLANTS?

READ MORE

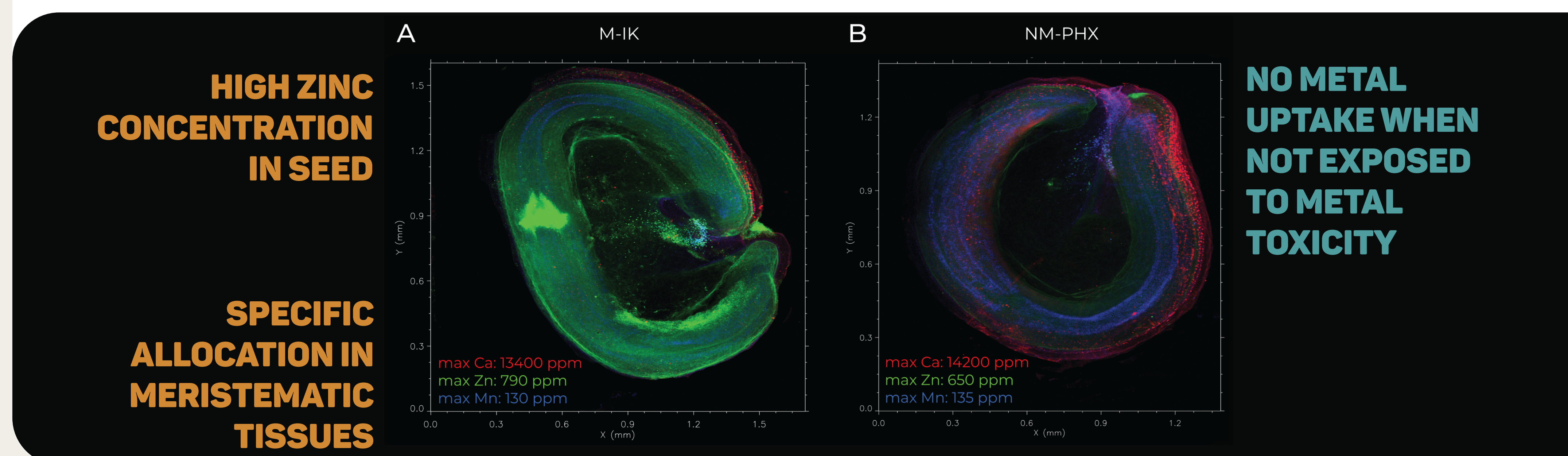


Fig. 2. The XFM maps showing the elemental distribution of Zn (green), Mn (blue), and Ca (red) inside the seeds of the *Atriplex lentiformis* plant. (A) Seed from population growing in metal-contaminated soil; (B) seeds from population grown in natural, non-contaminated soil.

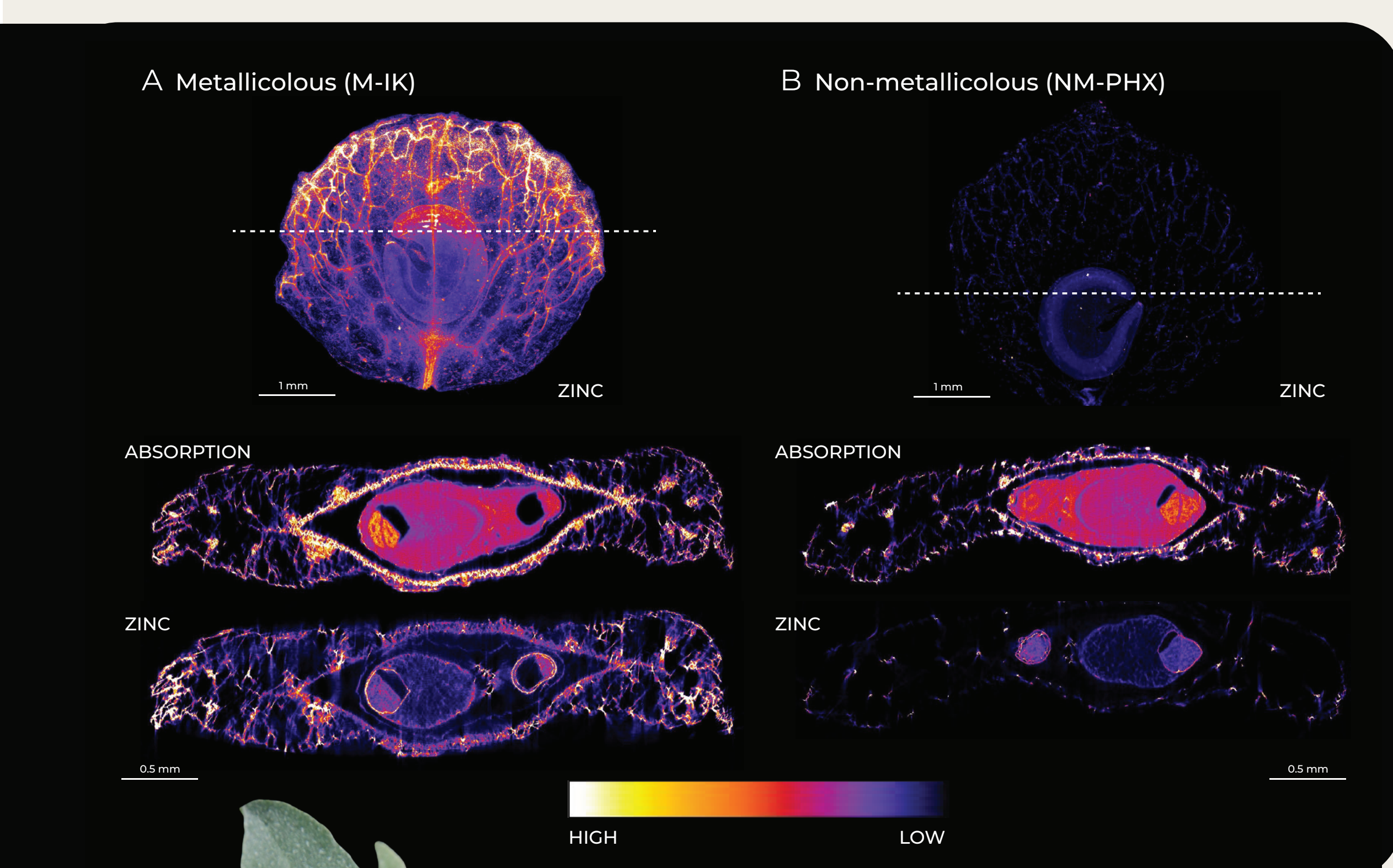


Fig. 3. Single-slice X-ray fluorescence microscopy (XFM) tomograms of *Atriplex lentiformis* seeds within the achene revealing the presence of Zn in intact tissues in metallicolous (A) and non-metallicolous (B) populations.

CONCLUSIONS

In summary, the results of the study suggest that **metal-contamination leads to adaptive strategies and the acquisition of specific metal-tolerance traits in both mature plants and seeds.**

Such information can be used to help optimize adaptive strategies and metal-tolerance mechanisms to improve performance and survival of these plants under harsh conditions.

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Atriplex lentiformis is perennial halophyte, native to semiarid regions of southwestern USA and northern Mexico, and is known to tolerate elevated concentrations of metals in soil, including Zn, Cd, As, and Pb. Such plants can play a pivotal role in restoration efforts, especially in regions where evaporation rates exceed precipitation.