Why do some plants thrive in toxic metal-contaminated soils, while others perish? The answer may lie not in the plants themselves — but in the microscopic allies living in their tissues.

This research project investigates the invisible partnerships between plants and soil microbes that help them survive and adapt to life in hostile environments, such as metal-rich soils. In these extreme conditions, some plants develop remarkable strategies: they either accumulate toxic metals in their tissues (a trait called hyperaccumulation) or exclude them to avoid toxicity. But neither strategy works alone. The microbes surrounding and inhabiting plant roots — their microbiota — play a crucial role in these adaptations.

The core question of this project is: how do plants shape and select their microbial partners under stress? Just as we rely on gut bacteria to digest food and support immunity, plants rely on their microbiota to absorb nutrients, manage stress, and defend against toxins. However, we still don’t fully understand how this partnership forms — or how microbes influence the plant's ability to take up or block metals.

Using a combination of fieldwork and laboratory experiments, the project compares plants with different metal-tolerance strategies to explore how each recruits and interacts with specific microbes. It will also examine the chemical signals that plants release to communicate with microbes and how, in turn, microbes influence plant gene expression — including key regulators of metal uptake and detoxification.

A unique aspect of this project is its focus on microbial engineering: understanding plant–microbiota relationships well enough to design beneficial microbial communities that can be applied to plants growing in contaminated soils. This could revolutionize phytoremediation — using plants to clean up polluted environments — and help make agriculture more resilient to environmental stress.

The results will contribute to a growing scientific view of the plant not as a solitary organism, but as a “holobiont” — a team of plant and microbes co-evolving and adapting together. By decoding the rules of this partnership, we can better understand nature’s solutions to extreme stress and apply them to solve some of today’s most pressing environmental challenges.