The Best of Both Soils:
Plant-Microbe Interactions in Serpentine and Nonserpentine Environments

By Alexandria Igwe, graduate student at UC Davis and winner of Donald Mayall Graduate Research Scholarship. July 2018.

Soil found at Coyote Ridge, McLaughlin Natural Reserve, Hopland Research and Extension Center and Jasper Ridge Biological Preserve have one thing in common: they were created through the weathering of ultramafic rock which is comprised primarily of magnesium-ferrous silicate minerals (Figure 1, [1,2]). Soil created from ultramafic rocks or serpentine soil is a treasure which facilitates the growth of 13% of the California's endemic plant species although it covers only about 1% of state [3]. Serpentine soil contains high amounts of magnesium, relatively low amounts of essential plant nutrients such as nitrogen, phosphorus, and potassium and elevated concentrations of heavy metals which contribute to

Figure 1-Picture of adjacent nonserpentine and serpentine site at Hopland Research and Extension Center. (Inset) Various rocks comprised of magnesium-ferrous silicate minerals frim which serpentine soil is derived. The peridotite rocks are (clockwise) Lherzolite, Harzburgite, Dunite, and Wehrlite.

low plant productivity and high rates of endemism on the soil [4]. Still, there are plants which are undeterred by the soil-related challenges imposed by serpentine while also retaining the ability to compete in nonserpentine environments (unlike their endemic counterparts). How are these serpentine-indifferent plants able to experience the best of both soils? That is a question I hope to partially answer by studying plant-microbe interactions using DNA-based molecular tools on microbes that associate with the roots of California plantain (*Plantago erecta*), Bird's-eye gilia (*Gilia tricolor*), Spinster's blue-eyed Mary (*Collinsia sparsiflora*), and Bull clover (*Trifolium fucatum*).

Microbes are able to help plants tolerate plant stress via a variety of mechanisms such as producing extracellular polymeric substances (EPS), fixing nitrogen, solubilizing phosphorus, and capturing heavy metals (Figure 2; [5]). Additionally, plants have been shown to tolerate stressful condition by associating with a microbial community that contains closely related microbes as opposed to unrelated microbes - a phenomenon referred to as phylogenetic clustering. My goal is to understand if and how these processes help serpentine-indifferent plants thrive in serpentine soil and compete with other plants on nonserpentine soil. To do this, the DNA was extracted from microbes associated with the roots of serpentine-indifferent plants that were grown in serpentine or nonserpentine soil. Using next-generation sequencing technology and statistical computing, the identity of microorganisms, microbial community composition, and phylogenetic clustering of soil types were determined.

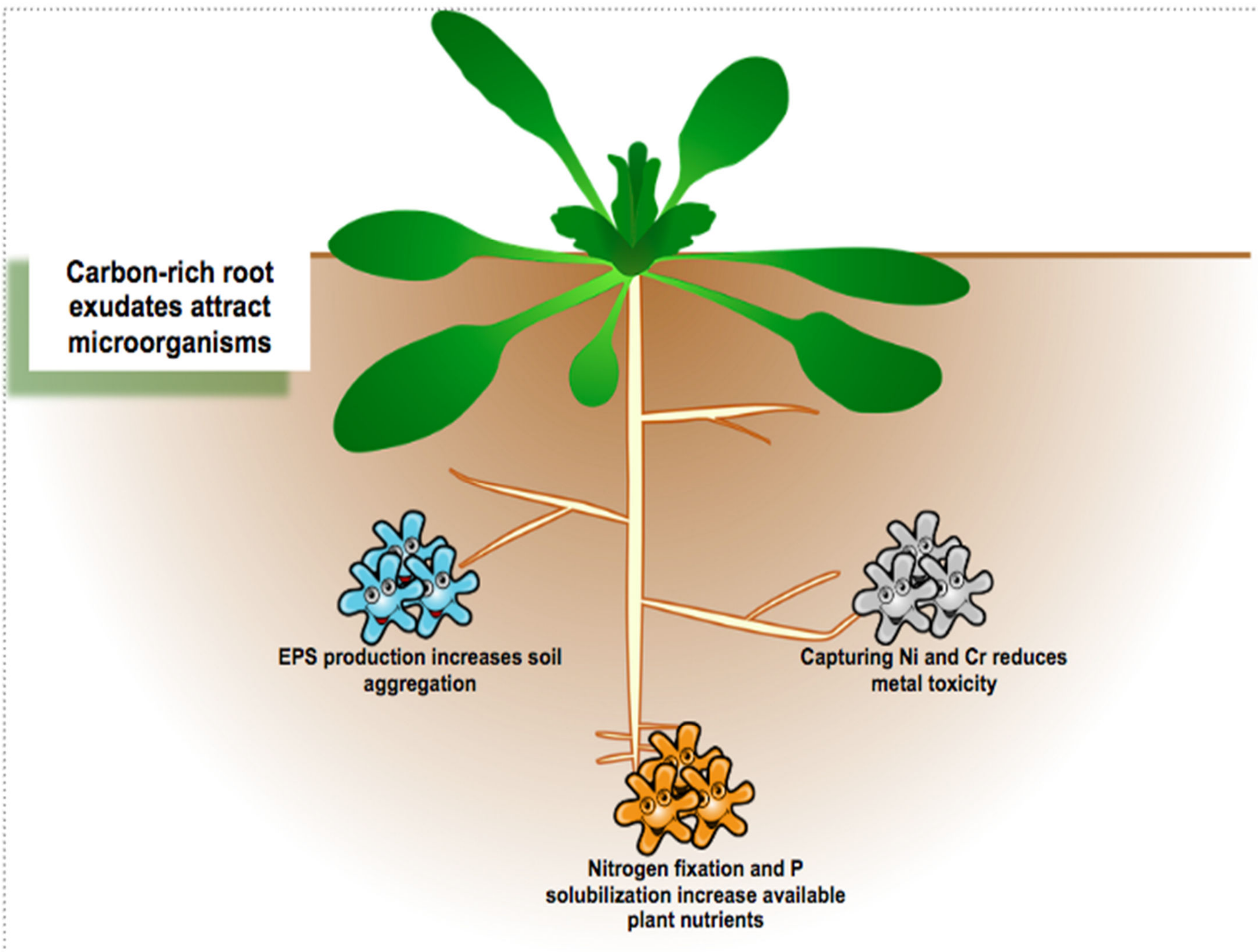

Figure 2-Representation of plant-microbe interactions in a stressful soil environment.

Interestingly, serpentine-indifferent plants were shown to utilize microorganisms in various ways. For example, the Spinster's blue-eyed Mary, California plantain, and Bird's-eye gilia associate with different microbial communities depending on if it is growing in serpentine or nonserpentine environments. Conversely, the Bull clover associates with the same microbial community on both soil types. This suggests that Spinster's blue-eyed Mary, California plantain, and Bird's-eye gilia associate are able to get their needs met by associating with a variety of microorganisms while the Bull clover requires a more specialized suite of microbes to survive.

Due to the extreme soil conditions experienced by living organisms in serpentine soil, I expected phylogenetic clustering to play an important role in plant stress tolerance. However, this was generally not the case. Only the California plantain associated with a phylogenetically clustered microbial community. Even more intriguing, the microbial communities in nonserpentine soils were more phylogenetically clustered than microbial communities from serpentine soil! This suggests that the competition experienced by California plantain on nonserpentine soil may be a greater environmental challenge than the nutrient deficiency presented by serpentine soil.

Overall, there is still much to be learned about how plant-microbe interactions contribute to plant survival on serpentine and nonserpentine soil and future experiments can identify more nuanced plant-microbe relationships. Understanding these interactions can contribute to reclamation efforts of degraded and invaded serpentine areas and remediation efforts of heavy-metal contaminated industrial sites that use plant-based technologies. Serpentine soil comprises only a small portion of California's land area, but it is responsible for a significant amount of California's native plant biodiversity. Continued research in this area is necessary to preserve California's natural treasure so that future generation can explore, learn, and grow from its presence.

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