Is Soil Generalist Erysimum capitatum Differentially Adapted to Serpentine Soils Across California Serpentine Exposures?

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BACKGROUND

- Serpentine only covers 1.5% of the state but houses ~9% of CA endemics [1].
- Serpentine soil is stressful for plants because it contains heavy metals and is high in Mg and low in Ca [2].
- It has been used as a model system to study evolution for decades [3].
- Serpentine formations can be highly variable in heavy metals, physical properties, and parent material [2] but most studies treat all serpentine as homogeneous environments [4, 5].
- Few studies have addressed how differences in serpentine may cause plants to locally adapt to their soil of origin [4].
- Erysimum capitatum (Brassicaceae) is widespread in western North America, categorized as a soil generalist, and found in patchy populations [6, 7].
- E. capitatum occupies numerous distinct serpentine formations with nearby populations inhabiting non-serpentine soil.
- This makes it an ideal system to see if local adaptation is occurring between pairs of serpentine and non-serpentine populations and to test if serpentine populations are adapted to their specific serpentine soil.

QUESTIONS

Q1. Are E. capitatum populations growing on serpentine soil as compared to nearby non-serpentine populations?

Q2. Does a serpentine ecotype of E. capitatum exist?

Q3. Do E. capitatum populations experience differential success when grown in their home serpentine vs other serpentine soils?

METHODS

Greenhouse Reciprocal Transplant
- Seeds collected from E. capitatum populations found on paired serpentine (n=4) and non-serpentine soil sites (n=4) across CA latitudinal gradient (Fig 3.)
- Soil was collected from the four serpentine sites.
- Seeds from 6-8 mothers at each site were germinated and planted into each of the soils plus control sandy loam soil (43 seeds x 8 pops x 5 soils =1720 plants).
- Planting occurred in Dec 2022.
- Monthly data collected on longest leaf length, leaf count, and mortality.
- After 6 months of growth, shoot and root biomass were weighed.
- All data analyzed in R.

RESULTS

Q1 Results: Local Adaptation Found in 2 Serpentine Populations

- All data analyzed in R.
- Monthly data collected on longest leaf length, leaf count, and root biomass.
- No significant differences in performance across sites (Table 1).

Q2 Results: No Serpentine Ecotype

- Evidence for an ecotype was not seen because not all serpentine populations were locally adapted.

Q3 Results: No Home Serpentine Advantage

- Serpentine populations did not exhibit any preference to growing in their home serpentine soil.

Other Results: Trend on Soil A

- All serpentine populations on serpentine Soil A outperformed the non-serpentine populations.
- Conserved trait shared across serpentine populations for serpentine tolerance.
- Soil analyses revealed high amounts of heavy metals: Fe, Ni, Mn, and Co in this soil only. Soil parent material dominantly Peridotite and Harzburgite.
- Heavy metal tolerance well known in other serpentine Brassicaceae.

CONCLUSIONS

- There is a conserved trait for serpentine tolerance within E. capitatum serpentine populations possibly linked to heavy metal tolerance. More experiments testing populations on other high heavy metal serpentine is needed.
- Serpentine soils are diverse and the variation between exposures should be considered in botanical studies. Therefore, conducting experiments including serpentine from varying exposures is important to identifying differing adaptation.

REFERENCES AND ACKNOWLEDGMENTS

Funding provided by the Myers Trust, Northern California Botanists, SJRU SESC, and SJSU Biology Department Fellowship. Thank you to my advisors, field helpers, undergraduate assistants, and the department staff who made this work possible.

Alumnae listed by Charlotte Miranda.

Figure 1. Serpentine, the parent material for serpentine soil in New Idria, CA.

Figure 2. E. capitatum growing in serpentine soil in New Idria, CA.

Figure 3. Map of E. capitatum serpentine and non-serpentine field site locations across CA with photos of individuals from each serpentine population. Map created using QGIS.

Figure 4. Cone-tainers of serpentine soils.

Figure 5. E. capitatum populations growing in home serpentine soils and non-serpentine soil. Top row showing longest leaf length comparisons and bottom row showing root:shoot ratios. Soil C excluded due to total mortality. Analyzed using Wilcoxon rank sum test with continuity correction. Significant p-values bolded.

Figure 6. Population pairs after 6 months.

Figure 7. All E. capitatum populations growing in Serpentine Soil A. Left graph showing longest leaf length comparisons and right graph showing root:shoot ratios. Analyzed using Kruskal Wallis rank sum test with post hoc Dunn Test. Significant p-values bolded.