Plant-based methods to remediate arsenic in a proposed urban agriculture site: effects of soil texture and fertilization

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INTRODUCTION

- **A major barrier to** proliferation of **urban agriculture is soil contamination.**
- **Arsenic (As) soil contamination is widespread,** a result of mining activities, coal combustion, pesticide use, and irrigated agriculture.
- **Phytoremediation with the As-hyperaccumulating fern *Pteris vittata* L. (Fig. 1) has emerged as an *in situ* technology to remediate soils with shallow As contamination.** While the mechanisms of As uptake and accumulation in the fern have received attention in numerous greenhouse and hydroponic experiments, only a few studies have investigated the fern's performance under field conditions. Understanding field performance under complex and heterogeneous conditions is crucial to developing successful *in situ* remediation methods.
- **We designed this project in response to community interest** in the fern's potential to remove As from the site of a proposed neighborhood orchard.

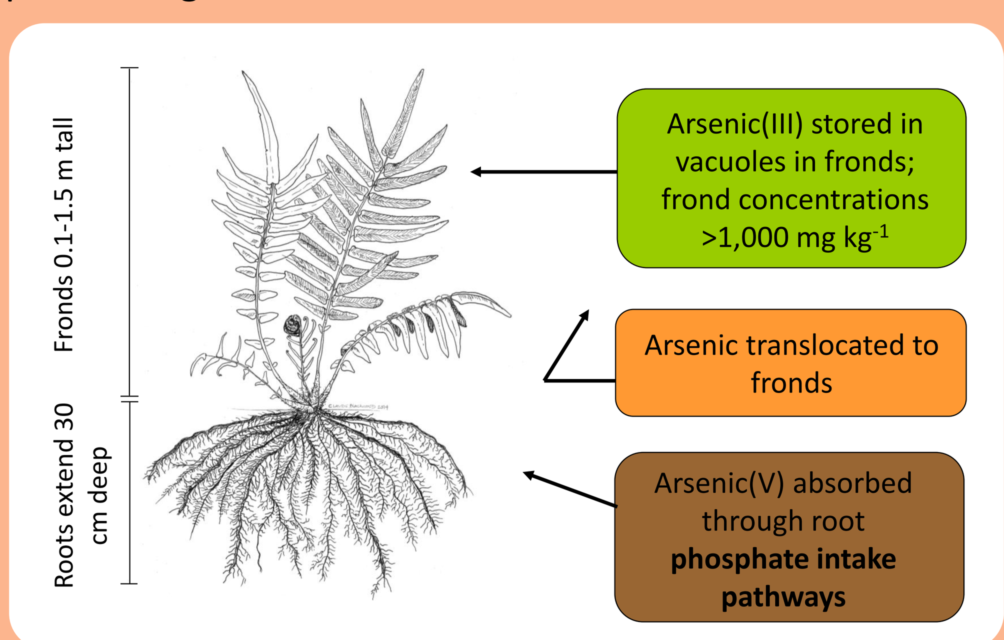


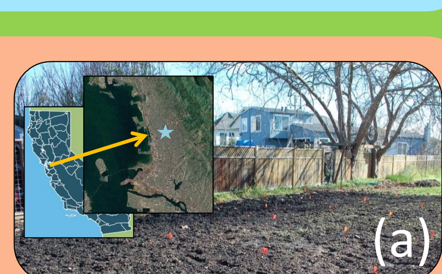
Figure 1. As hyperaccumulation in *Pteris vittata* L.

OBJECTIVE

To determine **the effects of soil texture and soil fertilization on As phytoextraction by *P. vittata*,** under field conditions, in order to optimize remediation efficiency

METHODS

Field site: An abandoned railroad right-of-way with heterogeneous soil texture (loamy sand to silty clay loam) contaminated with As (20-173 mg kg^{-1}), located in Berkeley (CA) (Fig. 2), characterized by a Mediterranean climate.



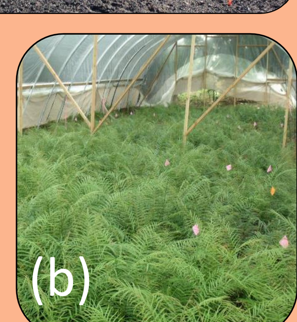


Figure 2. Tilled soil at field site (a); ferns in hoop house after 2 years (b)

Experiment design: Working with community collaborators, a 24m x 6m plot was tilled and limed (3,000 kg $CaCO_3$ ha^{-1}) before 1,600 *P. vittata* ferns were planted in February 2013 at 30 cm spacing. Five treatments were applied to separate plots at standard agricultural rates (Fig. 3). For comparison, we established a control plot with no treatments applied to ferns.

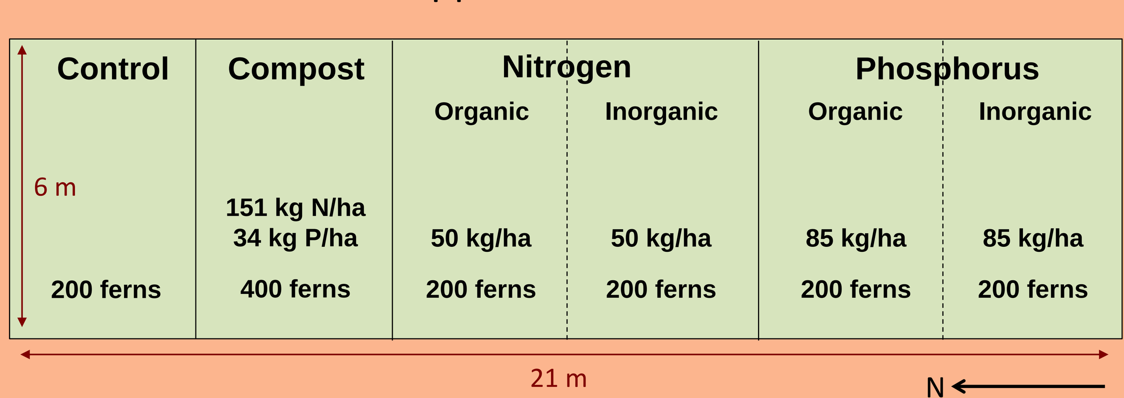


Figure 3. Field experiment schematic.

Data analysis: Fern fronds were harvested annually for 3 years. Ten percent of ferns in each treatment group were randomly selected to comprise representative samples. Individual ferns were kept separate throughout analyses. Arsenic concentrations were analyzed in fern samples using ICP-OES (EPA Methods 3050B and 6010B). Using one-way analysis of variance, significant differences in treatment effects were determined using Duncan's multiple range test, at $p<0.05$.

To determine soil texture, cores were taken along E-W transects at N and S ends of the plot, at 0-15 cm and 15-30 cm depths.

ACKNOWLEDGEMENTS

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DISCUSSION & CONCLUSIONS

- **Remediation rates are highest in control and compost-treated ferns**. The fern appears to prefer low or slow-release nutrient sources.
- **Frond As concentrations, biomass, and total As uptake were lower in clayey soil with lower soil As.** However, despite these lower uptake rates, the estimated remediation time to remediate this soil down to 10 ppm is 13 years, the lowest time we calculated, precisely because the soil has low As to begin with.
- **P treatments significantly lowered total As uptake and remediation rates** compared to the control, regardless of soil texture. P appears to successfully compete with As for uptake in the fern.
- Although the percentage of soil As removed is significantly lower in all treated plots compared to the control, texture does not affect the percent of soil As removed. This suggests the **fern can remove As capably from soils regardless of texture**, an important finding since As is typically less available in clay-textured soils.

FUTURE WORK

- Determine As uptake in vegetables grown in remediated and unremediated soils.

RESULTS: Soil As is highest in the sandy fill part of the railroad grade

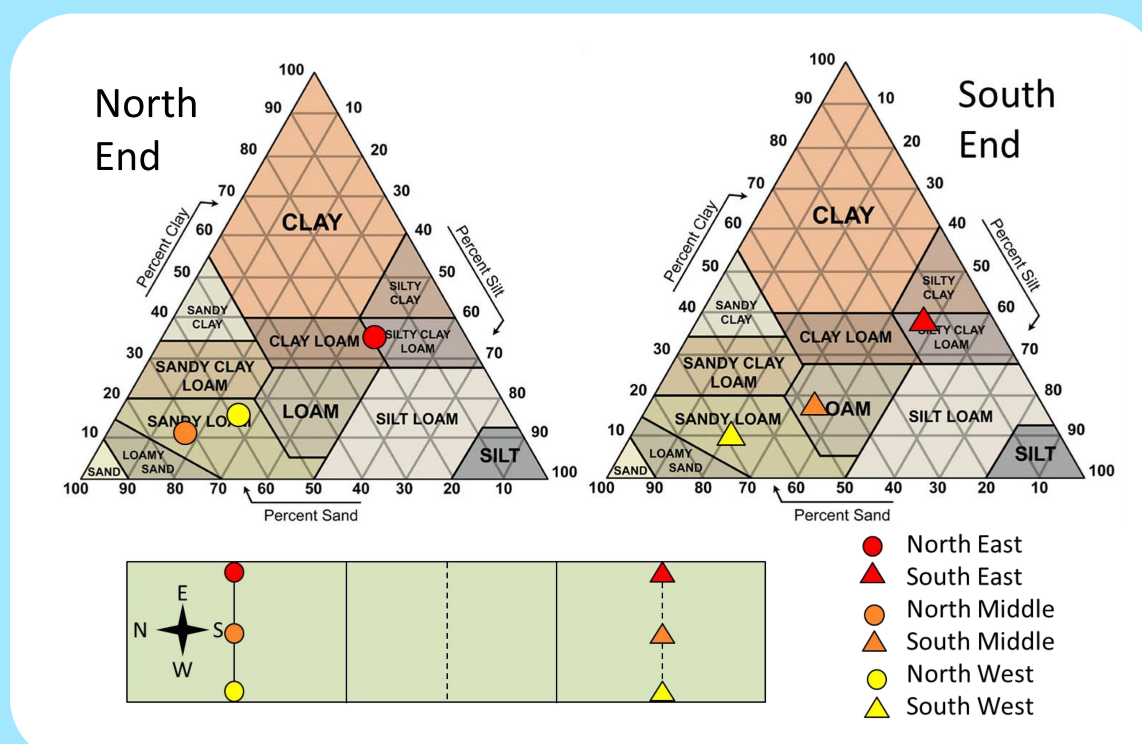

Figure 4. Soil texture within experiment plot 0-15 cm deep.

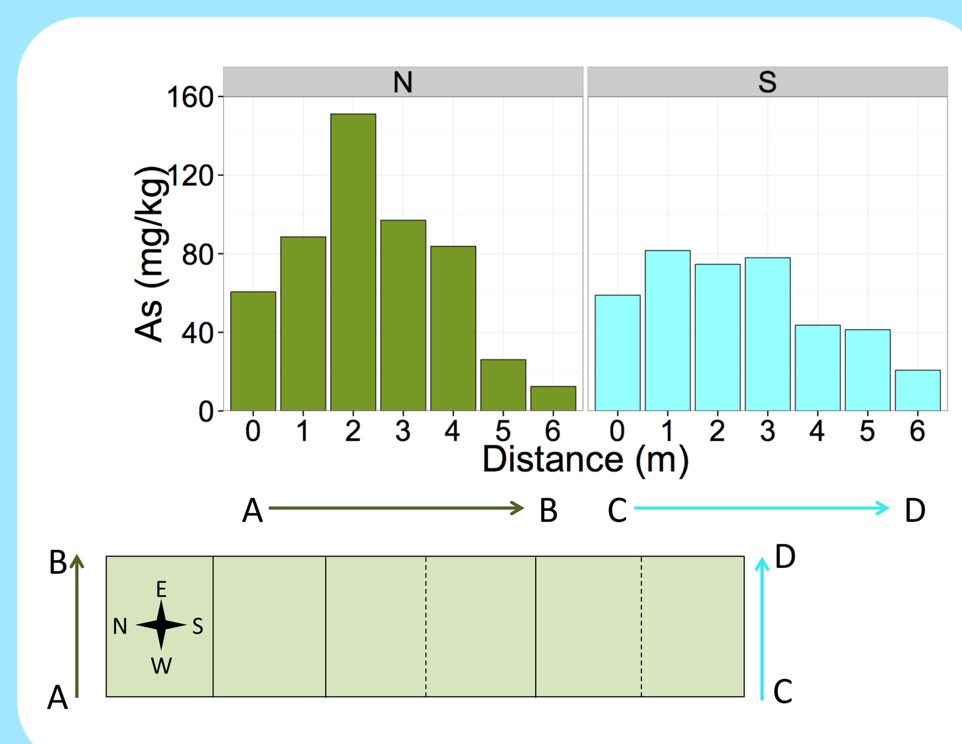

Figure 5. Surface soil As concentrations along transects outside of experiment plot 0-10 cm deep.

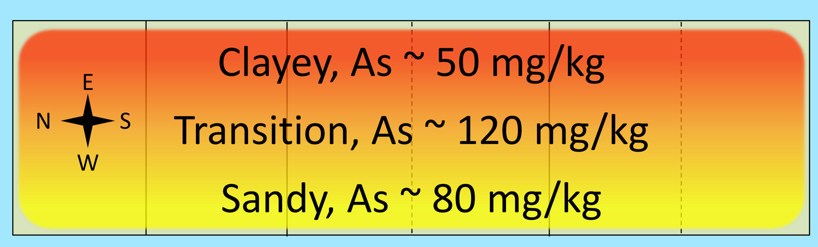

Figure 6. Soil texture and within-plot surface (0-10cm) As concentrations combined to yield three zones, used to interpret As uptake results (below).

RESULTS: Fertilization with P decreases phytoextraction efficiency

- Fertilization with **compost does not interfere** with phytoextraction
- **Remediation rates are faster in soils with higher As** (sandy textured soils)
- **Remediation rates are lower in P-treated ferns**, and slightly decrease over 3 years.

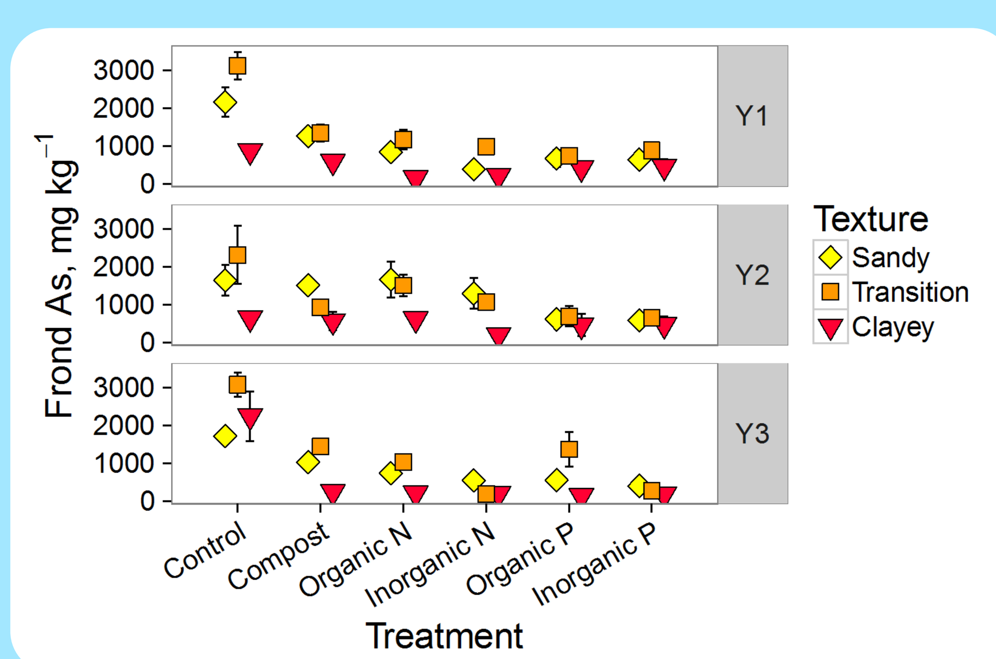

Figure 7. Effects of soil treatment and soil texture on As concentration in harvested biomass. n=14.

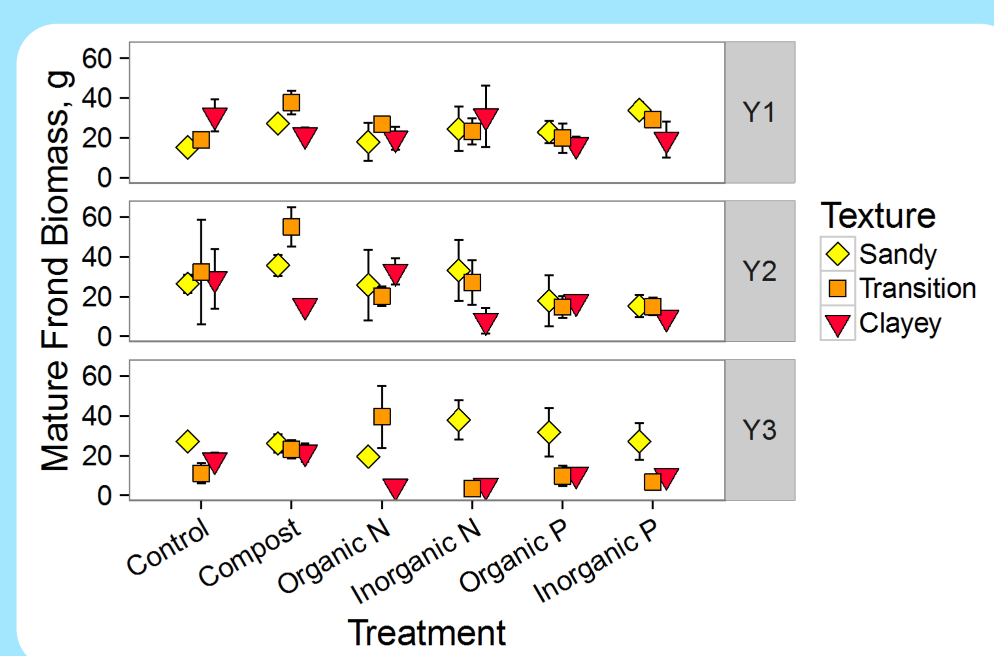

Figure 8. Effects of soil treatment and soil texture on harvested aboveground dry biomass. n=14.

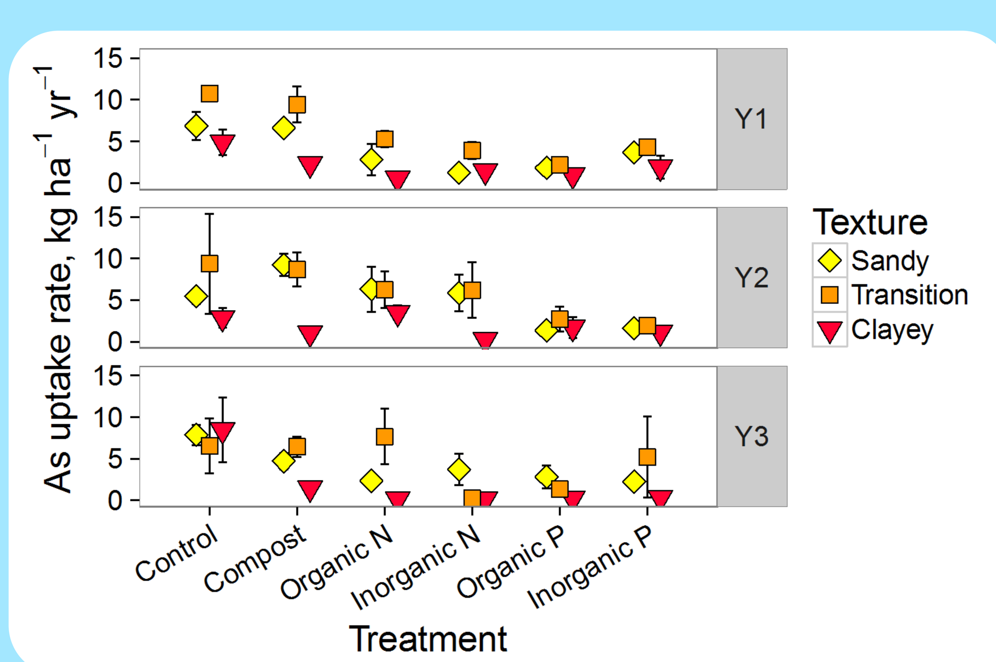

Figure 9. Effects of soil treatment and soil texture on rate of As uptake in ferns. n=14.

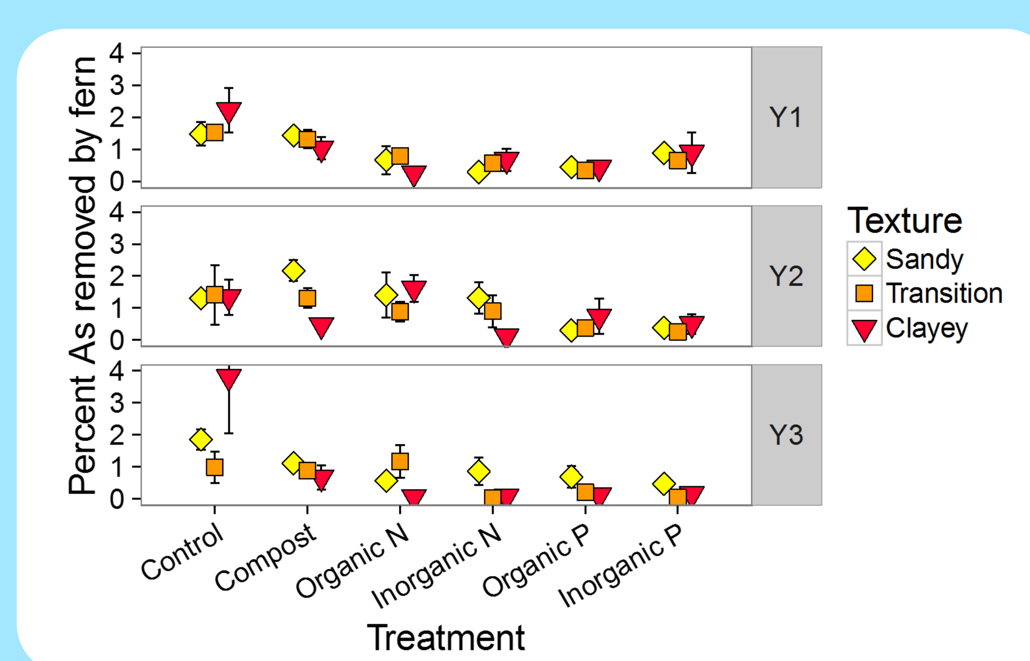

Figure 10. Effects of soil treatment and soil texture on the percent of soil As removed by ferns. n=14.