**INTRODUCTION**

As urban agriculture reclaim contaminated land, soil remediation methods that are cost-effective, sustainable, and broadly applicable are urgently needed. If proven viable, *in situ* remediation methods could be combined with urban agriculture to decrease exposure to legacy contaminants, improve urban soil health, and increase local food production.

Arsenic (As) soil pollution is gaining recognition as a widespread urban problem. Arsenic contamination can result from use of arsenical pesticides, treated wood, mining activities, and coal burning. In a recent study of almost 2,000 yards in cities across the US, 20% contained arsenic above a 10 mg kg⁻¹ action level [1].

Phytoremediation with the arsenic-hyperaccumulating fern *Pteris vittata* (picture above) [2] has emerged as a technology to remediate soils with shallow contamination. While the mechanisms of arsenic uptake and accumulation in *P. vittata* have received attention in numerous greenhouse and hydroponic experiments, only a few studies have investigated the fern’s performance under field conditions, which is crucial to developing successful remediation methods. The goal of this study is to develop new protocols to increase in situ arsenic phytoremediation efficiency and remediation time.

**OBJECTIVES**

To determine the effects of organic and inorganic fertilization on *P. vittata* frond biomass, arsenic uptake rate by *P. vittata*, and cumulative arsenic removal from soil.

**METHODS**

The field site is an abandoned railroad right-of-way (sandy loam) mildly contaminated with As (20-100 ppm), located in Berkeley (CA) and characterized by a Mediterranean climate. A 24m x 6m plot was tilled and limed (0.3 kg m⁻²) before 1,600 *P. vittata* ferns were planted at 30 cm spacing.

We tested 5 treatments, applied to fern beds at standard agricultural rates:
1) compost
2) organic nitrogen as blood meal (5 g N m⁻²)
3) inorganic nitrogen as (NH₄)₂SO₄ (5 g N m⁻²)
4) organic phosphorus as bone meal (20 g P₂O₅ m⁻²)
5) inorganic phosphorus as phosphate rock (20 g P₂O₅ m⁻²)

For comparison, we established a control plot with no treatments applied to ferns.

After 8 months of growth, all mature and senescing fronds were harvested. Ten percent of ferns in each treatment group were randomly selected to comprise our representative sample. Fronds were kept separated by individual fern throughout analysis. Arsenic concentrations were determined using ICP-AES. Using one-way analysis of variance, significant differences in treatment effects were determined using Duncan’s new multiple range test, at p<0.05. This poster presents results from the first third of our fern samples.

**SOIL CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Time</th>
<th>Depth (cm)</th>
<th>Control – No ferns</th>
<th>Control – Ferns</th>
<th>Compost</th>
<th>Blood Meal</th>
<th>(NH₄)₂SO₄</th>
<th>Bone Meal</th>
<th>Phosphate Rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>0-15</td>
<td>6.93±0.12</td>
<td>6.93±0.04</td>
<td>7.31±0.03</td>
<td>7.08±0.11</td>
<td>6.66±0.09</td>
<td>6.11±0.02</td>
<td>6.58±0.04</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>6.9**</td>
<td>7.02±0.07</td>
<td>7.46±0.04</td>
<td>7.22±0.10</td>
<td>6.64±0.28</td>
<td>6.59±0.18</td>
<td>6.82±0.08</td>
</tr>
<tr>
<td>C/N</td>
<td>0-15</td>
<td>12.73±0.85</td>
<td>12.73±0.85</td>
<td>13.76±0.60</td>
<td>13.76±0.60</td>
<td>13.76±0.60</td>
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<td>13.76±0.60</td>
</tr>
<tr>
<td></td>
<td>15-30</td>
<td>12.73±0.85</td>
<td>12.73±0.85</td>
<td>13.76±0.60</td>
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<td>13.76±0.60</td>
</tr>
</tbody>
</table>

Table 1. Soil pH and C/N values for experimental plots at two depths. Reported values are averages of 3 replicates, except for Control – Ferns and Compost values, which are averages of 6 replicates. H1 refers to first harvest (8 months of fern growth). **Due to limited sample size, this indicates one composite sample of 3 replicates.

**RESULT 1: Biomass production**

*Figure 1. Effects of soil treatment on weight of harvested biomass. n=10 for Control and Compost; n=5 for other treatments. Means with the same letters are not significantly different at p<0.05.*

**RESULT 2: Arsenic accumulation in fern fronds**

*Figure 2. Effects of soil treatment on arsenic concentration in harvested biomass. n=10 for Control and Compost; n=5 for other treatments. Means with the same letters are not significantly different at p<0.05.*

**RESULT 3: Arsenic removal from soil**

<table>
<thead>
<tr>
<th>Soil treatment</th>
<th>Initial As concentration in soil (mg kg⁻¹)</th>
<th>Average biomass yield at H1 (g plant⁻¹)</th>
<th>Arsenic uptake at H1 (mg plant⁻¹)</th>
<th>Total As removed (kg ha⁻¹ y⁻¹)</th>
<th>Estimated years to remediate our study site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>85.5±8.8</td>
<td>23.95</td>
<td>46.6</td>
<td>7.8</td>
<td>41</td>
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<tr>
<td>Compost</td>
<td>36.77</td>
<td>24.45</td>
<td>16.4</td>
<td>7.9</td>
<td>40</td>
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<tr>
<td>Blood Meal</td>
<td>16.93</td>
<td>17.3</td>
<td>7.3</td>
<td>2.9</td>
<td>109</td>
</tr>
<tr>
<td>Ammonium Sulfate</td>
<td>19.70</td>
<td>13.4</td>
<td>2.2</td>
<td>144</td>
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</tr>
<tr>
<td>Bone Meal</td>
<td>28.38</td>
<td>14.2</td>
<td>2.4</td>
<td>136</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2. Efficiency of different treatments for arsenic removal and estimated years for remediation to an assumed regulatory standard of 10 mg kg⁻¹. H1 refers to first harvest (8 months of fern growth).**

**IMPLICATIONS AND FUTURE RESEARCH**

Implications:
- Senesced fronds lost arsenic, possibly due to leaching back into soil at fern base. Timing harvesting to avoid senescence could improve arsenic removal by 12%.
- Compost showed the best ability to enhance both frond arsenic concentration and biomass.
- In phosphate-treated plots, ferns may have taken up phosphate preferentially over arsenate.
- The arsenic uptake rates we report for compost-treated ferns compare favorably with published uptake rates. Additional improvements in uptake and biomass production are needed to shorten remediation timescales.

Future work:
- Analysis of arsenic concentration in soil samples
- Conduct batch experiments to elucidate effects of fertilizers on arsenic phytoavailability
- Examine effects of fern planting density and harvest method on arsenic removal
- Determine the effects of multiple contaminants on the fern’s ability to remove arsenic

**REFERENCES**


**ACKNOWLEDGEMENTS**

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