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Water & Nutrient Stress Increase Root Exudation

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Water & Nutrient Stress
Increase Root Exudation

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Develop procedures to:

- Grow *healthy* plants under sterile conditions
- Manipulate root exudation with stress
- Quantify total organic carbon in exudates
- Determine composition of exudates using GC-MS
Implications for Phytoremediation

Our focus for the qualitative analysis: organic acids

The chelating properties of these compounds can be useful for phytoremediation, and they are a class of compound most likely to be found in root exudate.

- Increased plant uptake
- Co-metabolism
- Increased/decreased contaminant mobility
System for sterile culture
HPS lamps

Laminar flow hood
Treatments

- High NH$_4^+$
- K$^+$ stress
- Drought
- Flooding
Days After Planting

Trial 3 in growth chamber
Trial 4 in laminar flow hood
Trial 5 enclosed shoot
Trial 6 improved planting technique
Assessing microbial contamination
Verifying Plate Counts: Acridine Orange Stain of Leachate

Clean sample

10 μm

Root debris
Verifying Plate Counts: Acridine Orange Stain of Leachate

Contaminated sample

10 µm

bacteria
Phenolic Aniline
Blue Stain of Root

Clean root

10 μm
Contaminated root

Phenolic Aniline Blue Stain of Root

10 µm

bacteria
The K+ stressed plants had the highest amount of carbon exuded at any point in time. We think this is because the plants were releasing a compound to sequester K+ from the soil.
Cumulative carbon exuded per gram dry plant

<table>
<thead>
<tr>
<th></th>
<th>mg C exuded per g dry plant</th>
<th>Percent of control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Std. dev.</td>
</tr>
<tr>
<td>control</td>
<td>2.6</td>
<td>0.4</td>
</tr>
<tr>
<td>NH4+</td>
<td>2.3</td>
<td>0.1</td>
</tr>
<tr>
<td>K+</td>
<td>3.7</td>
<td>0.6</td>
</tr>
<tr>
<td>flood</td>
<td>3.8</td>
<td>0.9</td>
</tr>
<tr>
<td>drought</td>
<td>4.4</td>
<td>0.5</td>
</tr>
</tbody>
</table>
Primary types of exudates

Compounds released by roots

Sloughed-off cells
Based on the distribution of carbon released by the roots (mostly soluble with not much left on the sand), we conclude that the exudates we’re seeing are mostly compounds released directly from the root, not whole cells released from the root.
Unlike the TOC graph, organic acids were exuded in the largest amounts from the drought and flooding treatments. This may be due to buildup of osmotic potential to deal with the low water potentials in the drought treatment, or just leakier root cells due to the stress treatments.
What’s in the root vs. what’s released by the root

**Fumaric Acid**
- Root (mg/kg): 0, 500, 1000, 1500, 2000
- Exudate (mg/L): 0, 2, 4, 6, 8, 10, 12
- \( r^2 = 0.54 \)

**Succinic Acid**
- Root (mg/kg): 0, 100, 200, 300, 400, 500
- Exudate (mg/L): 0, 2, 4, 6, 8, 10, 12
- \( r^2 = 0.55 \)

**Oxalic Acid**
- Root (mg/kg): 0, 50, 100, 150, 200, 250, 300, 350, 400
- Exudate (mg/L): 0, 2, 4, 6
- \( r^2 = \text{ns} \)

**Malonic Acid**
- Root (mg/kg): 0, 20, 40, 60, 80, 100
- Exudate (mg/L): 0, 1, 2, 3, 4, 5, 6
- \( r^2 = \text{ns} \)
Conclusions

1. Stress increases root exudation. Drought and flooding treatments increased release of organic acids.

2. Concentrations of succinic and fumaric acid in the root correlated with amounts released by the root.