Introduction to IBG

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2011 – 2016 PhD, Soils & Biogeochemistry
2016 – 2017 Postdoctoral researcher

2014, 2016, 2017 Visiting Researcher
US Borlaug Fellow in Global Food Security

2017 –
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Department of Crop Sciences
Application of biochemistry to soil science

Typical biochemistry samples
• Single or handful of compounds in high concentrations
• Organic matter (often tissues and serums)

Soil samples
• Millions of compounds in low concentrations
• Dominated by minerals
**Tool**

- Infrared spectroscopy

**Development**

- Reducing mineral interference

**Application to Agroecosystem**

- SOM composition in organic tomato fields

### Soil enzyme assays

- **Phosphatase**

\[
\text{R} \text{O} \text{C} \text{O} \text{H} \rightarrow \text{R} \text{O} \text{P} \text{OH}
\]

### Accounting for mineral & DOM artifacts

- **Phosphatase**

\[
\text{C}_{6} \text{H}_{4} \text{O} \text{H} \rightarrow \text{C}_{6} \text{H}_{4} \text{OH}
\]

\[
\text{Acidic termination} \rightarrow \text{C}_{6} \text{H}_{4} \text{OH}
\]

- **Alkaline termination**

\[
\text{C}_{6} \text{H}_{4} \text{O} \text{H} + \text{CaCl}_2 + \text{Base} \rightarrow \text{C}_{6} \text{H}_{4} \text{OH} + \text{Ca}^2+ + \text{Cl}^-
\]

- **Spectrophotometry** (410 nm)
Soil fertility in weathered soils
• Softwood BC (pH 10.9) was substituted for peat in a 70-30 peat-perlite mixture
• Substrates were or were not adjusted to pH 5.8 and were used to grow marigolds for 9 weeks

### Biochar characterization
- Gasification (800 °C) of conifer timber species from the northern California Sierra Nevada:
- Treated by a greenhouse producer (Greener Latitudes, Petaluma, CA) by washing the BC with a proprietary mixture of seaweed extract, magnesium sulfate, chitin

  pH 10.85  
  EC of 515.6 ± 0.1 μS cm⁻¹  
  TOC 653 ± 8 mg g⁻¹  
  C:N 120.9 ± 2.9  
  CEC of 19.0 cmolc kg⁻¹  
  Ash content 166 mg g⁻¹  
  Available P 179.0 ± 2.9 μg g⁻¹  
  Available ammonium-N 0.04 ± 0.01 μg g⁻¹  
  Available nitrate-N 1.67 ± 0.07 μg g⁻¹

<table>
<thead>
<tr>
<th>BC (% vol.)</th>
<th>Substrate composition (%BC-Peat-Perlite)</th>
<th>Substrate pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0-70-30</td>
<td>no pH adj</td>
</tr>
<tr>
<td>10</td>
<td>10-60-30</td>
<td>pH adj</td>
</tr>
<tr>
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<td>20-50-30</td>
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<td>60-10-30</td>
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<tr>
<td>70</td>
<td>70-0-30</td>
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</tbody>
</table>
Differences in germination -> likely effect of PLA used to decrease pH in pH-adjusted treatments

![Box plots showing germination percentage against BC substitution (% of total substrate volume) for no pH adj and pH adj treatments.](image)

- **no pH adj**: F = 1.4, p = 0.24
- **pH adj**: F = 23.7, p < 0.0001

*Pyroligneous Acid/Wood Vinegar*
Marigold shoot biomass, flower number, and height similar across %BC substitution and pH adjustment at 9 weeks (flowering)

-no pH adj

-pH adj

F = 1.6
p = 0.17

F = 3.0
p = 0.02
Differences in leaf SPAD and N uptake

High SPAD in intermediate BC substitution rates (substrate pH = 6-8 at week 9)

No effect of pH adjusting substrates on above-ground N uptake
pH increased/decreased from initial pre-plant extremes

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<thead>
<tr>
<th>BC (% vol.)</th>
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</thead>
<tbody>
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<td>0-70-30</td>
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<tr>
<td>10</td>
<td>10-60-30</td>
<td>5.6 (no pH adj) 5.8 (pH adj)</td>
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<td>20-50-30</td>
<td>6.6 (no pH adj) 5.8 (pH adj)</td>
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<tr>
<td>30</td>
<td>30-40-30</td>
<td>7.7 (no pH adj) 5.8 (pH adj)</td>
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<td>40-30-30</td>
<td>8.2 (no pH adj) 5.8 (pH adj)</td>
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<td>9.3 (no pH adj) 5.8 (pH adj)</td>
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<tr>
<td>60</td>
<td>60-10-30</td>
<td>9.7 (no pH adj) 5.8 (pH adj)</td>
</tr>
<tr>
<td>70</td>
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<td>10.4 (no pH adj) 5.8 (pH adj)</td>
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</tbody>
</table>

F = 99.6  p < 0.0001
F = 17.6  p < 0.0001
BC and activated C able to sorb large amounts of Cu…

…compared to soil minerals…

…and this depends on the type of BC

• Walnut shell biochar produced in CA Central Valley
• High sorption capacity for Cu$^{2+}$
• Can biochar be used to mitigate Cu impacts on soil nutrient cycling?

Russell Ranch:
Long-term agricultural experiment (23 yr)

1. Forest (riparian)
2. Grassland
3. Organic Ag
4. Conventional Ag
5. No-Input Ag
Biochar influences Cu toxicity on nutrient-cycling soil enzymes

- Change in phosphatase activity relative to no Cu (%)

- Increasing Cu$^{2+}$

- 9 μm CuO MP (100 ppm)
- 9 μm CuO MP (1000 ppm)
- 45 nm CuO NP (100 ppm)
- 45 nm CuO NP (1000 ppm)
- 16 nm CuO NP (100 ppm)
- 16 nm CuO NP (1000 ppm)
- CuCl$_2$ (100 ppm)
- CuCl$_2$ (1000 ppm)

ConvAg, OrgAg, OrgAg + BC
Biochar influences Cu toxicity on nutrient-cycling soil enzymes

Change in phosphatase activity relative to no Cu (%)

Increasing Cu^{2+}

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- 45 nm CuO NP (100 ppm)
- 45 nm CuO NP (1000 ppm)
- 16 nm CuO NP (100 ppm)
- 16 nm CuO NP (1000 ppm)
- CuCl₂ (100 ppm)
- CuCl₂ (1000 ppm)

ConvAg  |  OrgAg  |  OrgAg + BC
Biochar influences Cu toxicity on nutrient-cycling soil enzymes

Change in phosphatase activity relative to no Cu (%)
Can arbuscular mycorrhizae (AM) protect host plants against soil heavy metal exposure?
Biochar?

Reduction

Co-precipitation

Physical adsorption

Functional groups complexation

Ion exchange

$\text{H}_2\text{O}$  $\text{Ca}^{2+}$, $\text{K}^+$  $\text{CO}_3^{2-}$, $\text{PO}_4^{2-}$
Additional/Potential BC Projects

- Use of biochar as locally available soil amendment for coffee farmers in Central America (Texas A&M, USAID)
- ? Biochar for in-situ immobilization of heavy metals (Pb, Cd)
  - Untangling pH effects from other mechanisms
- ? Biochar as a liming amendment in East/Central Africa?