The effects of biochar as a soil amendment on soil quality and plant growth

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The Effects of Biochar as a Soil Amendment on Soil Quality and Plant Growth: A Study for the North Carolina High County

Presented by:

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Jared Sanborn, M.S.
What is NEXUS?

- Research project to develop and integrate biomass greenhouse heating technologies to extend growing seasons for resource-limited farmers
- Biomass and renewable energy testing site with 20’ (7m) × 30’ (10m) off-grid greenhouse
NEXUS Project
Sustainable Greenhouse Production

Organic Waste → Heat & Soil amendment → Sustainable Greenhouse Production

- Organic Waste: Available feedstock on a small farm
- Heat & Soil amendment
- More local food
- Farmers’ income increase
- Clean local environment
- Extending growing season
- Increasing productivity
- GHG emissions reduction
When used as a soil amendment, biochar forms a dynamic substrate which provides numerous benefits, including increasing:

1. nutrient availability,
2. increasing soil water retention,
3. improving crop yield, and
4. sequestering carbon for hundreds to thousands of years.
• However, biochar's effectiveness largely depends on the biomass feedstock and the soil to which it is applied.

• Testing different feedstocks under different soil conditions is needed in order to gain a full picture of the potential of biochar.
Objectives

• To compare the effects of different types of biochar created from individual feedstocks on soil quality and plant growth in soils found in the North Carolina high country region, US.

• Understanding how different biochars interact with soil will allow farmers to make an informed decision about which biochar feedstock to use.
• What are the agronomic differences between the biochar-soil treatments based on biochar feedstocks?
• Which feedstock will create the largest impact on adolescent plant growth in High County loam soil?
• Is there an observable effect between the agronomic properties of the biochar-soil treatments and plant yield?
Methodology

- Pyrolized four (4) feedstocks in single biochar burn using NEXUS biochar kiln:

Sorghum  Fraser fir  Woodchip  Bone
Biochar Kiln

One “batch” can produce 20lbs (10kg) of biochar (500 °C) from 60lbs (30kg) of biomass plus over 150,000 Btus (158,000 kJ)
Pyrolysis

500 °C  30 min.
400 °C  56 min.
Biochars

- Sorghum
- Fraser fir
- Woodchip
- Bone
• Biochar was removed from the kiln and ground to roughly 2mm size.
• Our soil (Saunook loam obtained from a local farm – 12.7mm size) and biochar mixture rates of 1%, 5%, 10%, 50%, and 100% were all tested.
• Saturated soil for 24 hours, then allowed to drain for 24 hours.
• Dried in oven for 24 hours at 110°C.
• Measured difference in wet and dry mass for three samples of each treatment.
Water Holding Capacity

Average water holding capacity (% dry weight)

- Control
- Sorghum
- Wood Chip
- Fraser Fir
- Bone

Biochar mixture (% dry weight)

Water held (% dry weight)
Growth Experiment

- Two nutrient solutions were prepared:
  1. Leachate from a commercial composting facility
  2. Hydroponics nutrients (i.e., FloraMicro + FloraGro).
- Created samples comprised of soil, nutrient, and **1%** biochar by dry mass (+20 MT/ha).
- Added sunflower seed.
- Watered equal amount daily.
Growth Experiment

- Matrix of all treatments and abbreviations (75 samples)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Control (C) (No nutrient mix)</th>
<th>Hydroponics Nutrients (H)</th>
<th>Compost Leachate (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (C) (No biochar mix)</td>
<td>CC</td>
<td>CH</td>
<td>CL</td>
</tr>
<tr>
<td>Sorghum (S)</td>
<td>SC</td>
<td>SH</td>
<td>SL</td>
</tr>
<tr>
<td>Fraser Fir (F)</td>
<td>FC</td>
<td>FH</td>
<td>FL</td>
</tr>
<tr>
<td>Woodchip (W)</td>
<td>WC</td>
<td>WH</td>
<td>WL</td>
</tr>
<tr>
<td>Hog Bone (B)</td>
<td>BC</td>
<td>BH</td>
<td>BL</td>
</tr>
</tbody>
</table>
Growth Experiment
Growth Experiment

- Harvested after 35 days, collected six data points, and calculated five more.

- Collected:
  1. Shoot length
  2. Root length
  3. Root fresh mass
  4. Root dry mass
  5. Shoot fresh mass
  6. Shoot dry mass

- Calculated:
  1. Total length
  2. Total fresh mass
  3. Total dry mass
  4. Dry root to shoot ratio (RSR)
  5. Dry shoot mass to shoot length (mg/mm)
## Soil analysis

<table>
<thead>
<tr>
<th></th>
<th>Humic Matter (g/100cc)</th>
<th>Weight by Volume Ratio (g/cc)</th>
<th>Cation Exchange Capacity (meq/100cc)</th>
<th>% Base Saturation</th>
<th>pH</th>
<th>P (mg/dm³)</th>
<th>K (mg/dm³)</th>
<th>Ca (mg/dm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control soil</td>
<td>0.22</td>
<td>0.96</td>
<td>11.40</td>
<td>84.67</td>
<td>5.80</td>
<td>17</td>
<td>301</td>
<td>1248</td>
</tr>
<tr>
<td>Bone biochar mix</td>
<td>0.22</td>
<td>0.97</td>
<td>14.53</td>
<td>88.67</td>
<td>5.97</td>
<td>213</td>
<td>381</td>
<td>1792</td>
</tr>
<tr>
<td>Sorghum mix</td>
<td>0.22</td>
<td>0.94</td>
<td>11.13</td>
<td>85.33</td>
<td>5.73</td>
<td>24</td>
<td>391</td>
<td>1177</td>
</tr>
<tr>
<td>Fraser fir mix</td>
<td>0.22</td>
<td>0.94</td>
<td>11.23</td>
<td>85.33</td>
<td>5.83</td>
<td>19</td>
<td>313</td>
<td>1227</td>
</tr>
<tr>
<td>Woodchip mix</td>
<td>0.22</td>
<td>0.92</td>
<td>10.77</td>
<td>84.67</td>
<td>5.83</td>
<td>17</td>
<td>275</td>
<td>1162</td>
</tr>
</tbody>
</table>
Data Analysis

• Difference of means:
  – 1) Analyzed biochar, 2) nutrients, and 3) biocharXnutrient (synthesis) treatments.
  – Change in means as a percent of control mean.
  – Allows for dimensionless comparison across all measurements.
### Data Analysis

- **Difference of means by biochar isolated effects**

<table>
<thead>
<tr>
<th></th>
<th>Sorgum</th>
<th>Fraser Fir</th>
<th>WoodChip</th>
<th>Bone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shoot length (mm)</strong></td>
<td>4%</td>
<td>-6%</td>
<td>-19%</td>
<td>8%</td>
</tr>
<tr>
<td><strong>Root Length (mm)</strong></td>
<td>-9%</td>
<td>-8%</td>
<td>-3%</td>
<td>3%</td>
</tr>
<tr>
<td><strong>Total length (mm)</strong></td>
<td>-4%</td>
<td>-7%</td>
<td>-10%</td>
<td>5%</td>
</tr>
<tr>
<td><strong>Fresh shoot mass (g)</strong></td>
<td>0%</td>
<td>1%</td>
<td>-5%</td>
<td>10%</td>
</tr>
<tr>
<td><strong>Fresh root mass (g)</strong></td>
<td>25%</td>
<td>36%</td>
<td>58%</td>
<td>10%</td>
</tr>
<tr>
<td><strong>Fresh total mass (g)</strong></td>
<td>8%</td>
<td>13%</td>
<td>16%</td>
<td>10%</td>
</tr>
<tr>
<td><strong>Dry root mass (g)</strong></td>
<td>13%</td>
<td>0%</td>
<td>9%</td>
<td>-22%</td>
</tr>
<tr>
<td><strong>Dry shoot mass (g)</strong></td>
<td>-1%</td>
<td>-3%</td>
<td>4%</td>
<td>12%</td>
</tr>
<tr>
<td><strong>Dry total mass (g)</strong></td>
<td>6%</td>
<td>-2%</td>
<td>7%</td>
<td>-5%</td>
</tr>
<tr>
<td><strong>mg/mm</strong></td>
<td>-2%</td>
<td>5%</td>
<td>29%</td>
<td>4%</td>
</tr>
<tr>
<td><strong>RSR</strong></td>
<td>12%</td>
<td>7%</td>
<td>9%</td>
<td>-8%</td>
</tr>
</tbody>
</table>
### Data Analysis

**Effects of adding nutrients with sorghum biochar**

<table>
<thead>
<tr>
<th></th>
<th>SC</th>
<th>SH</th>
<th>SL</th>
<th>CC</th>
<th>CH</th>
<th>CL</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Shoot length (mm)</strong></td>
<td>---</td>
<td>-19%</td>
<td>-17%</td>
<td>---</td>
<td>-25%</td>
<td>-7%</td>
</tr>
<tr>
<td><strong>Root Length (mm)</strong></td>
<td>---</td>
<td>-6%</td>
<td>4%</td>
<td>---</td>
<td>2%</td>
<td>-18%</td>
</tr>
<tr>
<td><strong>Total length (mm)</strong></td>
<td>---</td>
<td>-12%</td>
<td>-6%</td>
<td>---</td>
<td>-10%</td>
<td>-13%</td>
</tr>
<tr>
<td><strong>Fresh shoot mass (g)</strong></td>
<td>---</td>
<td>15%</td>
<td>-3%</td>
<td>---</td>
<td>3%</td>
<td>14%</td>
</tr>
<tr>
<td><strong>Fresh root mass (g)</strong></td>
<td>---</td>
<td>16%</td>
<td>18%</td>
<td>---</td>
<td>-6%</td>
<td>42%</td>
</tr>
<tr>
<td><strong>Fresh total mass (g)</strong></td>
<td>---</td>
<td>15%</td>
<td>6%</td>
<td>---</td>
<td>0%</td>
<td>24%</td>
</tr>
<tr>
<td><strong>Dry root mass (g)</strong></td>
<td>---</td>
<td>-27%</td>
<td>-14%</td>
<td>---</td>
<td>-10%</td>
<td>-9%</td>
</tr>
<tr>
<td><strong>Dry shoot mass (g)</strong></td>
<td>---</td>
<td>32%</td>
<td>4%</td>
<td>---</td>
<td>-7%</td>
<td>20%</td>
</tr>
<tr>
<td><strong>Dry total mass (g)</strong></td>
<td>---</td>
<td>1%</td>
<td>-5%</td>
<td>---</td>
<td>-8%</td>
<td>5%</td>
</tr>
<tr>
<td><strong>mg/mm</strong></td>
<td>---</td>
<td>62%</td>
<td>18%</td>
<td>---</td>
<td>23%</td>
<td>29%</td>
</tr>
<tr>
<td><strong>RSR</strong></td>
<td>---</td>
<td>-42%</td>
<td>-14%</td>
<td>---</td>
<td>4%</td>
<td>-26%</td>
</tr>
</tbody>
</table>
Conclusions

• Based on the results of the study, Sorghum biochar has provided the most promise for a useful soil amendment (highest WHC and high yielding).

• Conversely the addition of nutrients to control soils had a lesser and non-significant impact. Indicating that sorghum biochar may make the nutrients more available to the plants.
Conclusions

• Bone did show much higher levels of nutrients, specifically P in the soil tests. Bone biochar behaved differently than the other biochars.
• It is sometimes hard to tell what effects caused what (murky)
Further Research

• This study had lots of breadth (five soil types and three nutrient types, including controls), but more research could be done in depth for any aspect (e.g., other % mixture rates, other soil types).

• The results of this experiment have a strong indication but are far from conclusive.

• Growth test should be both short term and multiple growing cycles long.
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* NC Department of Agriculture and Consumer Services

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Thank you
Grazie
謝謝
Gracias
Danke
cпасибо
ありがとう
감사합니다

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