Utilization of manure feedstock biochars as P fertilizer for cotton

Agricultural Research Service, USDA
Agricultural Research Service

• USDA’s chief scientific in-house research agency
• Over 2000 scientists and post-doctoral researchers
• 90+ research locations (in US and abroad)

Vision

… to lead America towards a better future through agricultural research and information.
Coastal Plains Soil, Water, and Plant Research Center

Florence, SC

10 research scientists

Research focus:
- Cotton Genetics
- Manure
- Soil
- Water
Biochar

- myriad uses (industrial, municipal, agricultural)
- agricultural
  - emission reduction/adsorption
  - soil amendment
    - conditioning/reclamation, increase soil fertility
    - increase water retention, reduce N leaching
  - fertilization
    - nutrients (N, P, K, etc)
Biochar as Phosphorus Fertilizer?

- Limited nutrient
  - peak production (predicted 2033)
  - declining supply / increased prices
  - subject to geopolitical influences
    - major supplies are in Morocco, China, Western Sahara
    - reserves in Iraq, Algeria, Syria
Biochar as Phosphorus Fertilizer?

- Raw manure
  - not nutrient dense
    - limited transportation
  - excess nutrients
    - particularly N and P
    - also Cu and Zn
  - active vs passive treatment
    - economics and the political/regulatory landscape
  - limited land application
    - based on nutrient loads
  - pathogens, antibiotic resistance (ARB/ARG)

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Experimental Setup

- pot study (6.1 kg)
- *Gossypium hirsutum*
- 5 biochar feedstocks
  - chicken litter
  - turkey litter
  - beef manure
  - dairy manure
  - swine manure
- Produced at two temperature’s
  - 350 °C and 700 °C
Experimental Setup (con’t)

- biochar amendment based on P content
  - rate equivalent of 40 mg/kg P$_2$O$_5$
- N added at 50 mg N per kg soil (NH$_4$Cl)
- control treatment = unamended soil
  - low P forest soil (Norfolk loamy sand)
- limed to pH 6.0 prior to biochar addition
- irrigated twice daily (0.25” water/pot/day)
- plants harvested on day 60
  - leaf and stem samples collected
## Phosphorus Amendment

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Desired application rate $\text{P}_2\text{O}_5$ (mg/kg)</th>
<th>Biochar application rate (g char/pot)</th>
<th>Biochar amendment rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D-350</td>
<td>40</td>
<td>10.59</td>
<td>0.20%</td>
</tr>
<tr>
<td>D-700</td>
<td>40</td>
<td>6.31</td>
<td>0.10%</td>
</tr>
<tr>
<td>B-350</td>
<td>40</td>
<td>9.35</td>
<td>0.15%</td>
</tr>
<tr>
<td>B-700</td>
<td>40</td>
<td>6.06</td>
<td>0.10%</td>
</tr>
<tr>
<td>C-350</td>
<td>40</td>
<td>5.13</td>
<td>0.09%</td>
</tr>
<tr>
<td>C-700</td>
<td>40</td>
<td>3.41</td>
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<tr>
<td>S-350</td>
<td>40</td>
<td>2.74</td>
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<tr>
<td>S-700</td>
<td>40</td>
<td>1.81</td>
<td>0.03%</td>
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<tr>
<td>T-350</td>
<td>40</td>
<td>4.07</td>
<td>0.07%</td>
</tr>
<tr>
<td>T-700</td>
<td>40</td>
<td>2.91</td>
<td>0.05%</td>
</tr>
</tbody>
</table>
Soil Phosphorus

Phosphorus 40 mg/kg rate final extractable soil P level = 23.7 mg/kg
Plant Growth Results

Correlations
Leaf Weight vs Leaf Area
$r = 0.979 \ (P = 0.0001)$

Leaf Weight vs Stem Weight
$r = 0.857 \ (P = 0.001)$

Stem Weight vs Leaf Area
$r = 0.795 \ (P = 0.003)$
Phosphorus Rate Results

P Rate = -76.3 + (46.35 x Biomass)

P0, P20, P40, P60, S700, D350, C350
Blank (15.9), D350 (60.4), C350 (49.8), S700 (64.6)
Nutrient Results (con’t)

Iron

Boxplot of LF_{Fe} 

Boxplot of ST_{Fe} 

Boxplot of Fe_{fn} 

Magnesium

Boxplot of LF_{Mg} 

Boxplot of ST_{Mg} 

Boxplot of Mg_{fn} 

Leaf 

Stem 

Soil
Yet More Nutrient Results

**Calcium**

- Boxplot of *L.F.* Ca
- Boxplot of *S.T.* Ca
- Boxplot of *Ca* fn

**Potassium**

- Boxplot of *L.F.* K
- Boxplot of *S.T.* K
- Boxplot of *K* fn

**Leaf**  
**Stem**  
**Soil**
Conclusions

- Manure-based biochars make effective P fertilizers
  - free of pathogens and ARB/ARG
  - equal to or greater P rate responses compared to P$_2$O$_5$
- Similar uptake rates to conventional fertilizers
  - macro- and micro- nutrients
  - no toxicity concerns
- Low addition rates
  - allow for coupling with other biochars for conditioning purposes