Biochar Effects on Soybean Growth and Nodulation

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Forward

Although biochar has roots that extend far into the past, it is still a poorly known product.

The technology that is used to produce biochar started in antiquity but pyrolysis is little known to researchers and the public.
Knowledge about how and why biochar works is being generated at an accelerating rate. However, little is known about practical aspects of working with biochar on farms and in gardens.

As biochar becomes more widely known and used, it will become possible to formulate best management practices for different biochar use types.
Effect of Biochar on Plant Growth

“The application of biochar to agricultural soils has the potential to greatly improve soil physical, chemical and biological conditions.”


“Other promoted benefits of biochar application to soil include increased plant productivity and reduced nutrient leaching. However, the effects of biochar are variable and it remains unclear if recent enthusiasm can be justified.”

The biochar treatments were found to increase the final biomass, root biomass, plant height and number of leaves in all the cropping cycles in comparison to no biochar treatments.


Many of the short-term effects of biochar on plant growth and soil behavior reported from laboratory studies were not observed in the field emphasizing the need for long term field trials to help inform agronomic management decisions involving biochar.

Jones and others (2012): Biochar-mediated changes in soil quality and plant growth in a three year field trial. http://www.lunduniversity.lu.se/o.o.i.s?id=12683&postid=2409838
Objectives: Effect of Biochar Types/Rates on Soybean Growth and Nodulation

1. Soybean (*Glycine max, Elgin 87*) growth in the presence of biochar
   1. Leaves
   2. Stems
   3. Pods
   4. Plant height
   5. Root length
   6. Root weight

2. Nodule development on soybean roots (rhizobia/plant symbiosis)
   1. Number of nodules
   2. Weight of nodules
Greenhouse Experiment: Treatments

Treatments were as follows:

- No Biochar – No Soybean (*Glycine max*)
- No Biochar – Soybean
- 2% Miscanthus Biochar (wt) – Soybean
- 5% Miscanthus Biochar (wt) – Soybean
- 2% Pine Biochar (wt) – Soybean
- 5% Pine Biochar (wt) – Soybean

All treatments were triplicated
The Soil

A cultivated Alfisol, 5 kg

CEC = 12.0 meq/100g
Neutralizable Acidity = 4.0 meq/100g
pH$_s$ = 5.48
OM = 2.9%

P = 21.3 kg/ha (19 lbs/A)  (Low)
K = 285 kg/ha (254 lbs/A)  (High)
Ca = 2090 kg/ha (1865 lbs/A)  (Medium)
Mg = 808 kg/ha (721 lbs/A)  (Very high)
S (SO$_4$-S) = 2.7 ppm (Medium)
Greenhouse Experiment

Soil samples were taken from each pot after 1-day, 3-day, 10-day, 30-day and 60-day intervals.

All pots were treated with 75 kg P per hectare.

Additional data from a similar experiment with switchgrass will be used here for comparison.

Experiment duration: 60 days
Ways to Produce Biochar: Types of Pyrolysis


1. **Fast**: Moderate Temp ~500° C. Short vapor residence time ~1 sec; Liquid (75%); Char (12%); Gas (13%)

2. **Moderate**: Moderate temperature ~500° C. Moderate vapor residence time ~10-20sec; Liquid (50%); Char (20%); Gas (30%)

3. **Slow**: Moderate temperature ~500° C. Very long vapor residence time ~5-30min; Liquid (30%); Char (35%); Gas (35%)

4. **Gasification**: High temperature >750° C. Moderate vapor residence time ~10-20sec; Liquid (10%); Char (20%); Gas (85%)
Biochar – Byproduct of Bioenergy Production from Lignocellulosic Biomass

Photo courtesy of International Biochar Initiative
How Do We Produce Biochar?
Biochar was Generated from a Variety of Feedstocks through Slow Pyrolysis
Biochar...

... is recalcitrant in the soil environment

(Lehmann et al., 2009)

... has sorption properties

(McLaughlin and Shields, 2012; Yao et al., 2012)
Biochar is charcoal with properties somewhat similar to activated charcoal. It is produced through the pyrolysis process that involves heating of the herbaceous or ligneous biomass in an $O_2$ deprived environment. In slow pyrolysis the biomass is heated to thermal values between 400 to 600 °C.
Areas of Interest: Experimenting with Biochar in Our Research Projects

- Effects of biochar on soil properties
- Nutrient cycling in the soil environment
- More efficient use of nutrients by plants in the presence of biochar (Little loss as nonpoint source polluters to drive eutrophication)
- Growth of agricultural crops in the presence of biochar
- Sorption properties of biochar in environmental remediation
- Biomass research/production
Results and Discussion

No Biochar: 1.24
2% Pine Biochar: 1.12
5% Pine Biochar: 1.04
2% Miscanthus Biochar: 1.13
5% Miscanthus Biochar: 0.92
Root Length (cm)

- No Biochar
- 2% Pine Biochar
- 5% Pine Biochar
- 2% Miscanthus Biochar
- 5% Miscanthus Biochar

Comparisons:
- B
- AB
- A
Root Dry Weight (grams)

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<tr>
<th>Condition</th>
<th>Root Dry Weight (grams)</th>
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<tr>
<td>No Biochar</td>
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<tr>
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<td>2.5</td>
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<tr>
<td>5% Pine Biochar</td>
<td>3.0</td>
</tr>
<tr>
<td>2% Miscanthus Biochar</td>
<td>3.5</td>
</tr>
<tr>
<td>5% Miscanthus Biochar</td>
<td>3.0</td>
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</table>

A, B, C notations indicate significant differences.
% Nitrogen-Kjeldahl Method

- Pine: 0.261175
- Cedar: 0.317025
- Oak: 0.421275
- Miscanthis: 0.431475
- Switchgrass: 0.7082
Leaf Area

B
1517.30 cm²

AB
43%

AB
43%

A
94%

A
82%

102%

85%

No Biochar

2% Pine Biochar

5% Pine Biochar

2% Miscanthus Biochar

5% Miscanthus Biochar

2% Switchgrass Biochar

5% Switchgrass Biochar
Developed Pods (Complete Seed Fill)

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<th>Number</th>
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<td>2% Pine Biochar</td>
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<tr>
<td>5% Pine Biochar</td>
<td>48%</td>
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<tr>
<td>2% Miscanthus Biochar</td>
<td>34%</td>
</tr>
<tr>
<td>5% Miscanthus Biochar</td>
<td>58%</td>
</tr>
<tr>
<td>2% Switchgrass Biochar</td>
<td>62%</td>
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<tr>
<td>5% Switchgrass Biochar</td>
<td>55%</td>
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</tbody>
</table>
Conclusions

The rate of biochar significantly affects its ability to impact soybean growth.

Root growth was significantly increased by application of 2% biochar but at 5% rate, root growth was reduced as indicated by the root dry weight.

Biochar produced from the herbaceous giant miscanthus feedstock increased root growth more than the ligneous pine biochar.
The herbaceous biochar significantly inhibit nodulation in soybean.

Pine biochar significantly promoted nodulation at 2% application rate but at 5% rate, when compared to control, no significant difference was observed.

The effect of biochar on stem height was influenced by the type of biochar.

Biochar significantly increased the leaf area in soybean. The herbaceous biochar showed a more significant effect on leaf area in soybean.
Conclusions
(Continued)

- Biochar significantly increased the number of pods (complete seed fill at stage R6 of soybean growth)
- The ability of biochar to enhance soybean growth is significantly affected by the biochar type (biomass precursor)
- Biochar as a soil amendment may contribute to sustainable use of N and P reducing nutrient flux from agricultural sites including feedlots into inland waters
- The soil amendment Biochar sequesters atmospheric CO$_2$ and can help farmers (and the environment) by reducing the need for agrochemicals
As for biochar:

“In the absence of eligibility for carbon credits, or simply to supplement a future income stream from carbon stabilization, it is likely that biochar addition to soil will proceed only where sufficient improvements in soil performance and productivity are perceived or assured.”

Thank you!