Earthworms, Root Health & Biochar

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Benefits of biochar to the soil

- Increase nutrient retention
- Increase water holding capacity
- Absorbs toxins, useful for site remediation, allelopathy
Fusarium crown and root rot

F. oxysporum f. sp. asparagi
F. proliferatum
Asparagus greenhouse trials with earthworms

- Pots filled with infested soil
- Earthworms added.
- Pots transplanted with asparagus.
Effect of earthworms on Asparagus Crown rot

<table>
<thead>
<tr>
<th></th>
<th>Root weight (g)</th>
<th>% roots lesions</th>
<th>Fluorescent Pseudomonads (Log cfu/g soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CK</td>
<td>28</td>
<td>14</td>
<td>5.12</td>
</tr>
<tr>
<td>EW</td>
<td>44*</td>
<td>7*</td>
<td>6.18*</td>
</tr>
</tbody>
</table>
Fluorescent Pseudomonads are beneficial bacteria that can protect plant roots
Asparagus is mycorrhizal

No Mycorrhizae

Mycorrhizae
So we know that earthworms can help suppress disease on asparagus.

The problem is how do we increase earthworm levels.
Asparagus is allelopathic

- Allelochemicals include:
  - Ferulic acid
  - Coumaric acid
  - Caffeic acid
  - Saponins

- Allelochemicals do not affect *Fusarium* pathogens.
- Allelochemicals reduce mycorrhizae and beneficial organisms like fluorescent pseudomonads and... Earthworms???
Earthworms Feeding Studies

25 Earthworms

Ground alfalfa sprinkled on top

1 day later
M = Sterile millet, AR = Asparagus Roots, G = Grape leaves, A = alfalfa
Asparagus residues suppress

Asparagus growth
Mycorrhizae
Beneficial bacteria
Earthworm activity
Can biochar restore soil health in old asparagus soils by absorbing toxins?
Biochar was added to soil in pots

Pots were drenched with allelochemicals.

Pots were transplanted with asparagus.
No Allelochemicals

Allelochemicals

Control Biochar

Control Biochar
Percent Disease estimated as the percentage of roots with lesions.

Colonies per cm of root
Biochar increases growth

Biochar reduces the number of lesions on the roots.
Effect on Nitrogen

µmoles/g tissue

Biochar rate %

1100
1150
1200
1250
1300
1350
0 1.5 3
Effect of Biochar on elemental composition of asparagus

- **Fe**:
  - 0% Biochar: 1.5 µmoles/g
  - 1.5% Biochar: 1.5 µmoles/g
  - 3% Biochar: 0.3 µmoles/g

- **Mn**:
  - 0% Biochar: 0.4 µmoles/g
  - 1.5% Biochar: 0.4 µmoles/g
  - 3% Biochar: 0.7 µmoles/g
<table>
<thead>
<tr>
<th>Biochar rate %</th>
<th>Rhizo. pH</th>
<th>Fluorescent Pseudomonads (log/g)</th>
<th>Fusarium densities log/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>6.9 a</td>
<td>5.6 a</td>
<td>3.8 a</td>
</tr>
<tr>
<td>1.5</td>
<td>7.2 a</td>
<td>5.5 a</td>
<td>3.9 a</td>
</tr>
<tr>
<td>3.0</td>
<td>7.3 a</td>
<td>6.0 b</td>
<td>3.8 a</td>
</tr>
</tbody>
</table>
Effect on Mycorrhizae

Line intersect method
Expressed as % of intersects colonized
Biochar increases AM
Can biochar protect asparagus from ground up asparagus roots colonized by *Fusarium* spp?

- Ground roots were added to potting mix at 0, 1, and 5 g/L.

- Biochar added at 3.5 g/L (roughly 10% v/v); half left untreated as controls.
Effect of biochar on root weights (g)
So we know that biochar can help absorb the toxins and suppress disease on asparagus.

The problem: how to get biochar down to the roots zone where the toxins are?

Could earthworms serve as delivery agents for biochar? Do earthworms like biochar?
Current studies

Are all biochars alike??

<table>
<thead>
<tr>
<th>Biochar</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>CQuest Biochar</td>
<td>Hardwood</td>
</tr>
<tr>
<td>Agrichar</td>
<td>Hardwood</td>
</tr>
<tr>
<td>Soil Reef</td>
<td>Hardwood</td>
</tr>
<tr>
<td>Pure Black</td>
<td>Mixed Hardwood</td>
</tr>
<tr>
<td>CT Charcoal</td>
<td>Hard &amp; Soft</td>
</tr>
<tr>
<td>Char1</td>
<td>Animal cage litter</td>
</tr>
<tr>
<td>Char2</td>
<td>Yard waste</td>
</tr>
<tr>
<td>Char3</td>
<td>Hardwood</td>
</tr>
</tbody>
</table>
Worm Biochar Bins, Expt 1 starting 5-9-11
These worms used for expts. 1-3

25 worms in each bin
4-25-11
With millet

4-26-11
图中显示了两个实验容器。左侧容器的日期为5-4-11，标签为“水添加”。右侧容器的日期也为5-4-11，标签为“水和小米添加”。
water and millet added
5-4-11 Water added

5-4-11 water and millet added
Percent disappearance over time
Earthworms obtain most of their nutrition from microbes.

Do Biochars differ in their ability to increase microbial densities in soils?
Each biochar was added to soil, incubated, and then serially diluted onto agar dishes to see if microbes were affected

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<th>Type of Material</th>
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<tbody>
<tr>
<td>CQuest Biochar</td>
<td>Hardwood</td>
</tr>
<tr>
<td>Best Energies</td>
<td>Hardwood</td>
</tr>
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<td>Char3</td>
<td>Hardwood</td>
</tr>
<tr>
<td>Activated carbon</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
</tr>
</tbody>
</table>
What physical characteristics of biochar are correlated with earthworm feeding?

- % C
- % H
- Surface area
- Porosity
- % Ash
- Volatiles
- pH
Field Studies

Treatments
Earthworms
The combination

Biochar
None
Conclusion

• Biochar can suppress Fusarium crown and improve growth in toxic asparagus soils.
• Biochar increases VAM colonization
• Biochar may be useful in replanting asparagus soils by restoring health
Conclusion

• Identifying the characteristics that encourage earthworm feeding remains elusive.
• Total percent carbon appears to be negatively associated with earthworm feeding.
Acknowledgements

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Peter Thiel, CT Agr. Exp. Sta.