Can Apple Replant Disease be Controlled through use of Compost?

Compost Council of Canada
Compost Matters in AC Workshop

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Acknowledgements

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Apple Replant Disease (ARD)?

World wide phenomenon of apple industries

Young apple trees in a newly re-planted old orchard site do not thrive.

Symptoms often non-specific, reduced terminal shoot growth, smaller leaves, shorter internodes, foliage may be chlorotic with purplish tinges

Disease complex: pathogenic soil fungi working in concert with plant parasitic nematodes

Causes economic losses to the grower (re-establishment costs $75,000 / ha)
Casual ARD organisms in Nova Scotia*

- *Pythium sp.*
- *Cylindrocarpon sp.*
- Combinations of these organisms.

<table>
<thead>
<tr>
<th>Potting medium amendment</th>
<th>Shoot height increase log$_{10}$ (mm)</th>
<th>Root volume log$_{10}$ (cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. None</td>
<td>2.459 (288)</td>
<td>1.085 (12.2)</td>
</tr>
<tr>
<td>2. <em>C. lucidum</em></td>
<td>2.417 (261)</td>
<td>0.957 (9.1)</td>
</tr>
<tr>
<td>3. <em>P. irregulare</em></td>
<td>2.357 (228)</td>
<td>0.941 (8.7)</td>
</tr>
<tr>
<td>4. <em>P. irregulare + C. lucidum</em></td>
<td>2.117 (131)</td>
<td>0.507 (3.2)</td>
</tr>
<tr>
<td>SEM</td>
<td>0.0312</td>
<td>0.0724</td>
</tr>
</tbody>
</table>

Significance of probability <0.001 <0.001

History of ARD management in NS

Has never been an issue until 2014 regulatory loss of pre-plant, broad spectrum agro-chemical soil fumigant

- Methylbromide (banned)
- 1,3 dichloropropene (banned)

Chloropicrin – only partially effective

Other semi-selectives: partially effective
Anticipatory research: 2001 hypothesis

• Replant disease is the result of the long term cultivation of a single crop in one site. This accumulates a population of micro-organisms, both parasitic or pathogenic, on apple roots. It alters the physical structure and chemical composition of the soil. Mature trees tolerate the condition because their new root growth continually expands into fresh soil……..

• Therefore, by returning the soil in an apple replant site to a more favourable soil structure, chemistry and microbiome, apple replant disease can be suppressed or even eliminated.

✓ Soil aggregation

Disease suppression increases with increasing rates of compost application.
Greenhouse experiments with ARD soils and apple seedlings

1. Non-pasteurized soil / perlite control
2. Non-pasteurized soil mixed with manure
3. Non-pasteurized soil mixed with compost
4. Pasteurized soil mixed with manure
5. Pasteurized soil mixed with compost
Composts used

Single source substrates:
- horse manure
- hog manure
- mink manure

Mixed with equal volumes of hay and dry leaves

Composted indoors in bins

Piles turned weekly, water addition as required

Composting for 8 weeks until odourless

Maximum composting temperature:
- 66.7 °C (horse)
- 68.9 °C (hog)
- 31.1 °C (mink)
## Properties of two ARD soils

<table>
<thead>
<tr>
<th>Sample</th>
<th>Class</th>
<th>pH</th>
<th>SO (H₂O)</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>Ca</th>
<th>Mg</th>
<th>S</th>
<th>CEC (me/100g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Orchard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horse Compost</td>
<td>LmSa</td>
<td>6.4</td>
<td>3.9</td>
<td>415</td>
<td>333</td>
<td>2866</td>
<td>515</td>
<td>67</td>
<td>15.2</td>
</tr>
<tr>
<td>Horse Manure</td>
<td>LmSa</td>
<td>6.4</td>
<td>3.9</td>
<td>415</td>
<td>333</td>
<td>2866</td>
<td>515</td>
<td>67</td>
<td>15.2</td>
</tr>
<tr>
<td>Hog Manure</td>
<td>SaLm</td>
<td>6.4</td>
<td>2.9</td>
<td>847</td>
<td>223</td>
<td>3401</td>
<td>455</td>
<td>59</td>
<td>14.7</td>
</tr>
<tr>
<td>Hog Compost</td>
<td>SaLm</td>
<td>6.4</td>
<td>2.9</td>
<td>847</td>
<td>223</td>
<td>3401</td>
<td>455</td>
<td>59</td>
<td>14.7</td>
</tr>
</tbody>
</table>

## Analyses of manures and composts

<table>
<thead>
<tr>
<th>Sample</th>
<th>% N</th>
<th>% P</th>
<th>% K</th>
<th>% Ca</th>
<th>% Mg</th>
<th>% C</th>
<th>C:N Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hog Manure</td>
<td>2.10</td>
<td>1.22</td>
<td>0.86</td>
<td>1.90</td>
<td>0.36</td>
<td>47.28</td>
<td>22.5</td>
</tr>
<tr>
<td>Hog Compost</td>
<td>2.66</td>
<td>1.24</td>
<td>1.12</td>
<td>2.49</td>
<td>0.46</td>
<td>37.78</td>
<td>14.2</td>
</tr>
<tr>
<td>Horse Manure</td>
<td>0.61</td>
<td>0.14</td>
<td>0.75</td>
<td>0.33</td>
<td>0.15</td>
<td>36.92</td>
<td>60.5</td>
</tr>
<tr>
<td>Horse Compost</td>
<td>0.64</td>
<td>0.20</td>
<td>0.78</td>
<td>0.57</td>
<td>0.15</td>
<td>40.92</td>
<td>63.9</td>
</tr>
<tr>
<td>Mink Manure</td>
<td>0.82</td>
<td>1.80</td>
<td>0.31</td>
<td>3.79</td>
<td>0.32</td>
<td>12.67</td>
<td>15.5</td>
</tr>
<tr>
<td>Mink Compost</td>
<td>0.66</td>
<td>1.13</td>
<td>0.34</td>
<td>2.55</td>
<td>0.21</td>
<td>7.90</td>
<td>12.0</td>
</tr>
</tbody>
</table>
Apple seedling heights (mm) after 8 weeks of growth

Control  Hog compost  Horse compost  Mink compost

Non-pasteurized  Pasteurized

a, b – significant different at the 0.05 probability level
Biological remediation of Apple Replant Disease with composts and animal wastes
Conclusion: greenhouse pilot

- Significant response to soil pasteurization confirmed presence of ARD in the two orchard soils

- When different composts were mixed with the ARD soils, the growth of apple seedlings was dependent on N supply

- The magnitude of growth response to pasteurization was also dependent on N supply when composts were mixed with the ARD soil.

- The incorporation of hog and mink composts appeared to show some promise as alternatives to agro-chemical soil fumigants
Into the field .......(no shortage of ARD sites)
Characteristics of the experimental soil

Orthic Humo-Ferric Podzol, locally known as Hebert soil
- often cemented subsoils
- low soil water retentivity (droughty)
- low CEC, naturally acid
- pH = 6.2 (limed), OM = 3.5%,
- $P_2O_5 = 1790$ and $K_2O = 399$ kg / ha
- in apple production since 1942
Exp. design and treatments

• 1) No soil treatment (neg. control)

• 2) Pre-plant soil fumigation only (pos. control, Telone C-17)

• 3) Deep ripping only

• 4) Deep ripping + fumigation

• 5) Deep ripping + compost incorporation

Randomized complete block, with 5 trts and 4 reps, 12 trees / EU
Planted to Honeycrisp / M4 rootstock
Composted hog manure

Chosen as it best alleviated ARD symptoms in a greenhouse study

Composted for 6 weeks, turned weekly or when the internal temperature of the pile exceeded 60°C, water added as needed.

Compost parameters 2.7% N  1.2% P  1.1% K  C:N 14.2.

Applied to plots by opening a trench 40 cm deep and 50 cm wide with a mouldboard plough centered on the planting row and filling it with compost at 0.17 m³ per m of tree row.

Harrowed over to cover the compost-filled trench and to loosen and level the soil.
Treatments implemented in the fall of 2001

Trees planted spring 2002

Data collection 2002 - 2007
Results*

• Pathogens isolated from apple roots in experimental orchard:
  - *Cylindrocarpon* and *Pythium* species confirmed
  - *Pratylenchus* (root lesion nematodes), counts:
    • Control 1860 per L soil
    • Other treatments (incl. compost) 0-750 per L soil

• Root activity in the 4th growing season:
  significantly greater numbers of fine roots in the compost treatments

Year
Planting 1 2 3 4 5 6 Mean Yr
TCA, cm²
0
5
10
15
20
25
30
35
40
NTC
DR
DRC
F
DRF
DRFC
2 x SEM, Mean Line; p = 0.019
F x (DR vs DRC), Mean Line; p = 0.021
(DR vs DRC), Quad Line; p = 0.019
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Yield (kg / tree)</th>
<th>TCSA (cm(^{-2}))</th>
<th>Yield Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
<td>2006</td>
<td>2007</td>
</tr>
<tr>
<td>Control</td>
<td>5.4(^c)</td>
<td>6.4(^b)</td>
<td>7.2(^d)</td>
</tr>
<tr>
<td>Fumigation</td>
<td>15.6(^a)</td>
<td>8.9(^b)</td>
<td>28.0(^bc)</td>
</tr>
<tr>
<td>Ripping</td>
<td>5.3(^c)</td>
<td>6.8(^b)</td>
<td>15.7(^d)</td>
</tr>
<tr>
<td>Ripping + Fumigation</td>
<td>8.6(^{bc})</td>
<td>6.4(^b)</td>
<td>21.6(^{cd})</td>
</tr>
<tr>
<td>Ripping + Compost</td>
<td>11.0(^b)</td>
<td>10.7(^{ab})</td>
<td>30.0(^{ab})</td>
</tr>
</tbody>
</table>
Summary

• Pre-plant compost incorporation has the potential to increase root activity in newly re-established apple orchards.

• Compost incorporation increased TCA, yield
  – did not appear to be the result of increased N, P, K uptake
  – specific alterations to the soil microbial community should be investigated.

• Compost incorporation shows good promise as a replacement for agro-chemical soil fumigants.

• Practical challenges
  – handling large volumes of compost on a commercial scale
  – incorporation of compost to significant soil depth not easy
Current Research
NSFGA-AAFC Project (4 years: 2019 – 2023)

“Clean technologies to mitigate the re-emerging threat of apple replant disease”

Objectives:

1. Elucidating the ARD complex at multiple sites in NS
2. Annual crops for biofumigation
3. Organics for improved soil health and microbiome
4. Carbon substrates for anaerobic soil disinfestation
5. Pre-plant root-soak treatments for nursery trees