Influence of Diverse Compost Products on Soil Bacterial and Fungal Community in Potato Production System

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Productivity Challenge

Average potato yield (Statistics Canada) per year

Factors reducing potato yields

- Rolling landscape, shallow soils
- Bare soil exposed in fall and spring
- Frequent soil tillage (e.g. for planting, hilling, harvest)
- Minimal crop residue returned to soil
- Short (mostly 2 year) rotations
- Intensive practices = decline in soil quality
Compost to the rescue?

**Potential benefit of compost**

- Improves soil quality
- Increased SOM, aggregation, water holding capacity
  - Decreased bulk density
- Reduced severity of soil borne pathogen diseases
- More predictable nutrient availability than raw manure
- Can increase potato yields – water holding capacity
- Increases microbial community diversity
Objective

Determine the effect of three compost products on soil physico-chemical properties, potato productivity and bacterial and fungal community diversity.

Three compost products:

SSOC: Municipal Source Separated Organic Compost
FPMC: Forestry and Poultry Manure Compost
FRC: Forestry Residue Compost
## Compost product properties

<table>
<thead>
<tr>
<th>Property</th>
<th>SSOC</th>
<th>FPMC</th>
<th>FRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>C:N</td>
<td>15</td>
<td>26</td>
<td>59</td>
</tr>
<tr>
<td>DM (%)</td>
<td>48</td>
<td>58</td>
<td>42</td>
</tr>
<tr>
<td>Ash (%)(^1)</td>
<td>55</td>
<td>73</td>
<td>55</td>
</tr>
<tr>
<td>pH</td>
<td>7.7</td>
<td>7.6</td>
<td>7.2</td>
</tr>
<tr>
<td>C (%)(^1)</td>
<td>25</td>
<td>15</td>
<td>23</td>
</tr>
<tr>
<td>N (%)(^1)</td>
<td>1.8</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>NH(_4)-N:NO(_3)-N</td>
<td>2.5</td>
<td>1.0</td>
<td>&gt;8.3</td>
</tr>
</tbody>
</table>

\(^1\)dry matter basis
Material and Methods

Experimental site and sampling
- Site located at AAFC, Fredericton, NB
- 2014: barley crop; 2015: potato crop
- October 2014: 45 tonnes ha\(^{-1}\) (dry weight basis)
- Randomized complete block design with four replicates
- Sampling done in October 2014 (after compost application), spring, summer and fall 2015

- **Treatments:**
  1. Control: no compost
  2. SSOC
  3. FPMC
  4. FRC
Material and Methods

Ancillary measurements
- Soil organic carbon (SOC)
- Particulate organic matter carbon (POM-C)
- Permanganate oxidizable carbon (POX-C)
- Soil pH
- Soil moisture
- Potato tuber yield

Bacterial and fungal community
- Amplicon-based metagenomics
  - 16S rRNA gene - bacteria
  - Ribosomal Internal transcribed spacer (ITS)
- Sequencing by Illumina MiSeq
Results

### Organic carbon improved soil structure

<table>
<thead>
<tr>
<th></th>
<th>Average C applied (tonnes ha$^{-1}$ yr$^{-1}$)</th>
<th>Bulk density 2015 (g cm$^{-3}$)</th>
<th>Permeability 2015 (cm hr$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>1.04</td>
<td>26.8</td>
</tr>
<tr>
<td>SSOC</td>
<td>11</td>
<td>0.98*</td>
<td>43.5*</td>
</tr>
<tr>
<td>FPMC</td>
<td>7</td>
<td>1.02</td>
<td>34.7</td>
</tr>
<tr>
<td>FRC</td>
<td>11</td>
<td>0.96*</td>
<td>38.6*</td>
</tr>
</tbody>
</table>

*Significantly different from the control

**More Carbon = More Benefits**

Results

Compost changes soil organic carbon pools

**Dissolved Organic Carbon**

- **Control**
- **SSOC**
- **FPMC**
- **FRC**

**Respiration**

- **Control**
- **SSOC**
- **FPMC**
- **FRC**

ANOVA ≤ 0.05
Results

- **Soil organic carbon**
- **Permanganate oxidizable carbon (POX-C)**
- **Particulate organic matter (POM-C)**

**ANOVA ≤ 0.05**

- Size fraction of soil organic matter between 0.053 and 2 mm
- Partially decomposed plant and organic material
Results

Soil pH

Gravimetric water content (GWC)

ANOVA ≤ 0.05
Results

Compost application did not affect potato yield

Results

Potato yields in 19 site-years commercial potato fields in New Brunswick (Canada) with and without FPMC application

Results – Relative abundance of phyla in composts

**Bacteria**
- Armatimonadetes
- Chloroflexi
- Gemmatimonadetes
- candidate_division_WPS-1
- Bacteroidetes
- Planctomycetes
- Verrucomicrobia
- Actinobacteria
- Proteobacteria
- Acidobacteria

**Fungi**
- Ascomycota
- Basidiomycota
- Zygomycota
- Rozellomycota
- Chytridiomycota
- Glomeromycota

ANOVA ≤ 0.05
Results – biodiversity indices of composts

**Bacteria**

- **Chao1 richness**
  - SSOC: c
  - FPMC: b
  - FRC: a

- **Pielou’s evenness**
  - SSOC: a
  - FPMC: b
  - FRC: b

**Fungi**

- **Chao1 richness**
  - SSOC: a
  - FPMC: a
  - FRC: b

- **Pielou’s evenness**
  - SSOC: b
  - FPMC: a
  - FRC: b

ANOVA ≤ 0.05
Results – Compost Microbiome

β-diversity using multidimensional scaling (MDS)

**Bacteria**

- 2D Stress: 0.14

**Fungi**

- 2D Stress: 0.09

PERMANOVA p=0.004

PERMANOVA p=0.001
Results – Soil Microbiome

Relative abundance averaged over time (%)

**Bacteria**

- Acidobacteria
- Proteobacteria
- Actinobacteria
- Planctomycetes
- Verrucomicrobia
- Bacteroidetes
- Chloroflexi
- Candidate division WPS-1
- Gemmatimonadetes

**Fungi**

- Ascomycota
- Basidiomycota
- Zygomycota
- Chytridiomycota

ANOVA ≤ 0.05

* Significant differences from Control
Results - Soils

Relative abundance (%)

### Acidobacteria

- Control
- SSO
- FPMC
- FRC

ANOVA ≤ 0.05
Results - Soils

Relative abundance of bacterial species

<table>
<thead>
<tr>
<th>Composts</th>
<th>Soils – 2 weeks after application</th>
<th>Soils – 11 months after application</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTU2 Arthrobacter</td>
<td>OTU2 Arthrobacter</td>
<td>OTU1 Acidobacteria Gp6</td>
</tr>
<tr>
<td>OTU49 Sporosarcina</td>
<td>OTU1 Acidobacteria Gp6</td>
<td>OTU3 Acidobacteria Gp4</td>
</tr>
<tr>
<td>OTU42 Thiobacillus</td>
<td>OTU8 Massilia</td>
<td>OTU4 Acidobacteria Gp16</td>
</tr>
<tr>
<td>OTU43 Pseudomonas</td>
<td>OTU3 Acidobacteria Gp4</td>
<td>OTU6 Spartobacteria</td>
</tr>
<tr>
<td>OTU56 Bacteria_unclassified</td>
<td>OTU4 Acidobacteria Gp16</td>
<td>OTU7 Bradyrhizobium</td>
</tr>
<tr>
<td>OTU28 Bacteria_unclassified</td>
<td>OTU6 Spartobacteria</td>
<td>OTU5 Acidobacteria Gp16</td>
</tr>
<tr>
<td>OTU33 Chloroflexi</td>
<td>OTU10 Acidobacteria Gp4</td>
<td>OTU47 Anaerolineaceae</td>
</tr>
<tr>
<td>OTU68 Planomicrobiurn</td>
<td>OTU12 Sphingomonadaceae</td>
<td>OTU10 Acidobacteria Gp4</td>
</tr>
<tr>
<td>OTU123 Bacteria_unclassified</td>
<td>OTU17 Acidobacteria Gp7</td>
<td>OTU19 Spartobacteria</td>
</tr>
<tr>
<td>OTU44 Cryobacterium</td>
<td>OTU11 Planctomycetaceae</td>
<td>OTU11 Planctomycetaceae</td>
</tr>
<tr>
<td>OTU40 Rhizobium</td>
<td>OTU40 Rhizobium</td>
<td>OTU12 Sphingomonadaceae</td>
</tr>
<tr>
<td>OTU23 Devosia</td>
<td>OTU16 Acidobacteria Gp16</td>
<td>OTU10 Acidobacteria Gp4</td>
</tr>
<tr>
<td>OTU21 Acidobacteria Gp6</td>
<td>OTU13 Rhizobiales</td>
<td>OTU11 Planctomycetaceae</td>
</tr>
<tr>
<td>OTU37 Microbacteriaceae</td>
<td>OTU15 Betaproteobacteria</td>
<td>OTU13 Rhizobiales</td>
</tr>
<tr>
<td>OTU71 Anaerolineaceae</td>
<td>OTU15 Betaproteobacteria</td>
<td>OTU18 Gemmatimonas</td>
</tr>
<tr>
<td>OTU85 Anaerolineaceae</td>
<td>OTU16 Acidobacteria Gp16</td>
<td>OTU15 Betaproteobacteria</td>
</tr>
<tr>
<td>OTU154 Bacteroidetes</td>
<td>OTU13 Rhizobiales</td>
<td>OTU17 Acidobacteria Gp7</td>
</tr>
<tr>
<td>OTU84 Polaromonas</td>
<td>OTU15 Betaproteobacteria</td>
<td>OTU16 Acidobacteria Gp6</td>
</tr>
<tr>
<td>OTU133 Methylocaldum</td>
<td>OTU26 Acidobacteria Gp6</td>
<td>U39 Unclass. Xanthomonadales</td>
</tr>
<tr>
<td>OTU61 Bacteria_unclassified</td>
<td>OTU14 Acidobacteria Gp7</td>
<td>OTU14 Acidobacteria Gp7</td>
</tr>
</tbody>
</table>

Control | SSOC | FPMC | FRC | Control | SSOC | FPMC | FRC
Results - Soils

Relative abundance of fungal species

Composts
- OTU7958 *Arthrobotrys*
- OTU6989 Unidentified fungi
- OTU4154 *Ascomycota*
- OTU848 *Ascomycota*
- OTU4026 *Mortierella*
- OTU7678 *Serendipita*
- OTU1074 *Mucor*
- OTU3200 *Mortierella*
- OTU6033 *Peziza*
- OTU7606 *Auriculariales*
- OTU1178 *Mortierella*
- OTU7620 *Blastobotrys*
- OTU7687 *Orbiellaceae*
- OTU1440 Unidentified fungi
- OTU752 *Scedosporium*
- OTU3457 Unidentified fungi
- OTU8178 *Coprinellus*
- OTU4463 *Ascomycota*
- OTU756 *Coprinopsis*
- OTU2193 *Sebacinales*

Soils – 2 weeks after application
- OTU5550 *Mortierella*
- OTU1239 *Mortierella*
- OTU5456 *Capnodiales*
- OTU1807 *Podospora*
- OTU1689 *Myrothecium*
- OTU2084 *Nectriaceae*
- OTU1093 *Podospora*
- OTU7057 *Sebacinales*
- OTU5548 *Alternaria*
- OTU6383 *Fusarium*
- OTU3728 *Capnodiales*
- OTU7193 *Mortierella*
- OTU2421 *Sordariomycetes*
- OTU3531 *Humicola*
- OTU4149 *Auriculariales*
- OTU310 *Humicola*
- OTU1299 *Mortierella*
- OTU1172 *Alternaria*
- OTU4594 *Spizellomyces*
- OTU2136 *Phallus*

Soils – 11 months after application
- OTU5456 *Capnodiales*
- OTU5548 *Alternaria*
- OTU1172 *Alternaria*
- OTU3728 *Capnodiales*
- OTU1239 *Mortierella*
- OTU5550 *Mortierella*
- OTU5940 *Fusarium*
- OTU1772 *Gibberella*
- OTU2421 *Sordariomycetes*
- OTU4151 *Apodus*
- OTU4484 *Pleosporales*
- OTU16 *Phaeosphaeriaceae*
- OTU7193 *Mortierella*
- OTU508 *Mucor*
- OTU6403 *Articulospora*
- OTU7992 *Cryptococcus*
- OTU1299 *Mortierella*
- OTU3854 *Colletotrichum*
- OTU2084 *Nectriaceae*
- OTU4149 *Auriculariales*
Results – biodiversity indices of soils

**Bacteria**

- **Chao1 richness**
- **Pielou’s evenness**

**Fungi**

- **Chao1 richness**
- **Pielou’s evenness**

ANOVA ≤ 0.05
Results - Soils

\( \beta \)-diversity among treatments - nMDS

**Bacteria**

2D Stress: 0.15

PERMANOVA \( p=0.001 \)

**Fungi**

2D Stress: 0.19

PERMANOVA \( p=0.001 \)
Results

β-diversity over time - nMDS

Bacteria

PERMANOVA p=0.001

2D Stress: 0.15

Fungi

PERMANOVA p=0.001

2D Stress: 0.19
Conclusions

- Compost application changed soil structure, nutrient levels and affected different labile soil organic carbon fractions.

- Compost changed the relative abundance of bacterial phyla in soils but not on the relative abundance of fungal phyla.

- Compost application resulted in a change in the diversity of bacterial and fungal communities that could be observed in the next growing season.

- Compost application did not result in an increase in potato yield.

- Compost is a good option to remediate poor quality soil but adoption by growers is difficult due to cost and the low potential for short-term return on investment.
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- Sean Whitney, Sara Neupane, Carolyn Wilson, Ginette Decker, Karen Terry, Kyle MacKinley
Composts

SSOC: organic curb-side waste composted in-vessel (Elmsdale Landscaping Inc.)

FPMC: windrow composting of poultry manure and wood shaving bedding, forestry wastes, paper mill residue, and wood ash (Brand RV045, Envirem Organics Inc.)

FRC: windrow composted predominantly from wood-waste feedstock including bark, paper mill residue, and wood-ash with approximately 5% broiler chicken manure (Black Earth, Envirem Organics Inc.).