Grapes, Wine, Balance and Soil Health

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Michigan State University
Presentation Overview

• Balance: How it Works
• Soil Biology in Action
• Soil Health Indicators
• Soil Health Maintenance-Remediation
Presentation Approach

• Tell me and I will forget.
• Show me and I might remember.
• Involve me and I will understand!
So Let’s Get Involved
So Let’s Get Involved

• How many of you are grape growers?
More Involvement

• How many of you grow grapes for:
  – Wine,
  – Juice,
  – Fresh Market?
More Involvement

• How many of you are grape growers?

• What is your concept (definition) of soil?
Soil

• **Habitat** for living organisms and a

• **Place** where matter and energy are transformed and transported.
Healthy Soil, Healthy Grapes and Good Wine

• Requires a balanced diversity of soil-borne organisms.
• Balanced transport and transformation of matter and energy.
Soil

• **Gaseous**
  – Soil atmosphere

• **Liquid**
  – Soil water

• **Solid**
  – Mineral matter (clay, silt, sand, loam)
  – Organic matter (decomposing, dead, humus, living)
Vineyard Soil Disturbance

- Physical,
- Chemical and
- Biological, resulting in
- Soil Health Degradation
Soil Health

A civilization, nation or food system is only as healthy as the health of its soil.
What the Michigan Potato Industry Learned in 2012

• Using a soil health score of 0-100, the 96 sites averaged a soil health score of 58.
More of what we learned in 2012

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• The longer the crop rotation, the higher the soil health score.
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• The longer the crop rotation, the higher the soil health score.

• The greater diversity of plants in the rotations, the higher the score.
More of what we learned.

• Using a soil health score of 0-100, the 96 sites averaged a soil health score of 58.
• The longer the crop rotation, the higher the soil health score.
• The greater diversity of plants in the rotations, the higher the score.
• One field had a soil health score greater than 80, the minimum required for classification as a healthy soil.
How Vineyard Soil Works
How Vineyard Soil Works

• Phase 1.

• Organic Matter Decomposition by:
  – Soil-borne bacteria
    • Feeding on soft and tough tissues
  – Soil-borne Fungi
    • Feeding on cell walls
Let’s get involved again.

What are the four types of organic matter in vineyard soil?

And the answers are.


Phase 1.

Carbon Transport and Transformation
How Vineyard Soil Works

• Organic Matter Decomposition

• **Fixation**: Organic matter transferred to soil-borne microorganisms through their feeding and is fixed (incorporated) into their bodies:
  • Soil Bacteria
  • Soil Fungi
Fixation Immobilization Sequestration

Energy $\rightarrow$ $\text{CO}_2$

Shoot System

Root System

$\text{H}_2\text{O}$ Nutrients

Sugar Exudate

Bacteria C:N 5:1

Phase 1.

Processes of Fixation and Mineralization Review

- **Ionic (inorganic) forms of matter used by plants as a source of nitrogen.**
  - $\text{NH}_4^+$
  - $\text{NO}_3^-$

- **Organic forms not directly usable**
  - Proteins (Amino Acids)
  - Nucleic Acids
  - Microbial cell wall (immobilization)

Nitrogen transport and transformation in soil and compost

Bird, 2004
How Vineyard Soil Works

- Organic Matter Decomposition
- Fixation

**Phase 2. Consumption (feeding):** Bacteria are consumed by your *soil-borne friends*:

- Nematodes
- Ciliates
- Rotifers
- Flagellates
- Amoebae
- Gastrotrichs
Role of nematodes, flagellates, ciliates and amoebae in nutrient mineralization

Phase 1.

Sugar Exudate

Phase 2.

Nematode C:N 10:1

Bacteria C:N 5:1

How Vineyard Soil Works

• Organic Matter Decomposition
• Fixation
• Consumption

• **Phase 3. Mineralization:** Your soil-borne friends release nutrients, such as nitrogen, in its ionic form (NH$_4^+$) into the rhizosphere (area surrounding the root).
Role of nematodes, flagellates, ciliates and amoebae in nutrient mineralization

Phase 1.
- Sugar Exudate
- Bacteria (C:N 5:1)

Phase 2.
- Nematode (C:N 10:1)

Phase 3.
- Rhizosphere
- \( \text{NH}_4^+ \)

How Vineyard Soil Works

- Organic Matter Decomposition
- Fixation
- Consumption
- Mineralization

- **Nitrification**: Specialized bacteria convert ammonium (NH$_4^+$) into nitrate (NO$_3^-$).
Four phases of soil-borne microorganism transport and transformation of matter and energy in soil.

Phase 1. Sugar Exudate

Phase 2. Bacteria C:N 5:1

Phase 3. Nematode C:N 10:1

Phase 4.

How Soil Works Review

- Organic matter decomposition
- Matter fixed into the bodies of microbes
- Bacteria consumed by other microbes
- Usable minerals released by microbes
- Nitrate made available by specialized bacteria
- Soil nutrients ready for grape production
How Soil Works
Action Movie
How do I know if my vineyard soil is healthy?

• The soil is not healthy if:
  – Poor grape quality
  – Poor quality wine
  – Inadequate vineyard/winery profitability
  – Grape yields are low
  – Through use of a set of soil health indicators
Vineyard Soil Health Indicators

• Water Stable Aggregates
  – (%)

[Image of test tubes]
Soil Health Indicators

- Water Stable Aggregates
- Water Holding Capacity
Soil Health Indicators

- Water Stable Aggregates
- Water Holding Capacity
- **Surface Hardness** (psi)
Soil Health Indicators

- Water Stable Aggregates
- Water Holding Capacity
- Surface Hardness

- Subsurface Hardness
Soil Health Indicators

- Water Stable Aggregates
- Water Holding Capacity
- Surface Hardness
- Subsurface Hardness
- Soil Organic Matter (%)

[Image of two vials with blue liquid]
Soil Health Indicators

- Water Stable Aggregates
- Water Holding Capacity
- Surface Hardness
- Subsurface Hardness
- Soil Organic Matter

- Active Carbon
Soil Health Indicators

- Water Stable Aggregates
- Water Holding Capacity
- Surface Hardness
- Subsurface Hardness
- Soil Organic Matter
- Active Carbon
- N Mineralization potential
Soil Health Indicators

- Water Stable Aggregates
- Water Holding Capacity
- Surface Hardness
- Subsurface Hardness
- Soil Organic Matter
- Active Carbon
- N Mineralization potential

- Soil Respiration
Soil Health Indicators

- Water Stable Aggregates
- Water Holding Capacity
- Surface Hardness
- Subsurface Hardness
- Soil Organic Matter
- Active Carbon
- N Mineralization potential
- Soil Respiration

- **Nitrification**
2015 Action Research Results

• What we learned from the actors (growers):
  – Productivity and profitability (short term)
  – Soil health (long-term)

• What we learned about indicators.
  – Water stable aggregates
  – Nitrogen mineralization potential
  – Active carbon
Soil Health Renovation/Maintenance Practices

• Minimize tillage
• Minimize toxic chemical inputs
• Mulch
• Cover crops
• Compost
Cover Crop Laws

• 1. Have a specific reason (objective) for using a cover crop.
Cover Crop Laws

• 1. Have a specific reason (objective) for using a cover crop.

• 2. Select the right cover crop cultivar (variety) for your objective.
Cover Crop Laws

• 1. Have a specific reason (objective) for using a cover crop.
• 2. Select the right cover crop cultivar (variety) for your objective.
• 3. Manage the cover crop in a manner designed to achieve the specific objective.

Bio-fumigation requires a very different type of management.
Primary Productivity

<table>
<thead>
<tr>
<th>System</th>
<th>Species Richness (taxa/100 cm$^3$ soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mature Eastern Deciduous Forest (Dynamic Equilibrium Phase)</td>
<td>46</td>
</tr>
<tr>
<td>Old Field Succession (Growth Phase)</td>
<td>35</td>
</tr>
<tr>
<td>Corn/Wheat/Soybeans/Clover (+tillage, -synthetic inputs)</td>
<td>27</td>
</tr>
<tr>
<td>Corn/Wheat/Soybeans (+tillage, +synthetic inputs)</td>
<td>27</td>
</tr>
<tr>
<td>Corn/Wheat/Soybeans (-tillage, +synthetic inputs)</td>
<td>19</td>
</tr>
</tbody>
</table>
## Organic Apple Orchard Soil After Seven Years of Transition

<table>
<thead>
<tr>
<th>Soil depth (0-30 cm)</th>
<th>Mulch</th>
<th>Tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil organic matter (%)</td>
<td>2.4</td>
<td>2.1</td>
</tr>
<tr>
<td>Carbon (tons/ha)</td>
<td>47</td>
<td>45</td>
</tr>
<tr>
<td>Nitrogen (mg/kg)</td>
<td>24</td>
<td>7</td>
</tr>
<tr>
<td>C mineralization (mg/kg)</td>
<td>1250</td>
<td>1050</td>
</tr>
<tr>
<td>N mineralization (mg/kg)</td>
<td>90</td>
<td>75</td>
</tr>
<tr>
<td><em>Pratylenchus penetrans</em> (root-lesion nematode) /100 cc</td>
<td>1</td>
<td>22</td>
</tr>
</tbody>
</table>

Zoppolo, Bird *et al.*, 2011
Nematodes/100 cc soil or litter.

Bird and Smith, 2013
<table>
<thead>
<tr>
<th></th>
<th>O Horizon</th>
<th>0 to 15 cm depth</th>
<th>15 to 30 cm depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flagellates</td>
<td>139,799b</td>
<td>5,758 a</td>
<td>2,634 a</td>
</tr>
<tr>
<td>Amoebae</td>
<td>39,380 b</td>
<td>9,321 a</td>
<td>1,515 a</td>
</tr>
<tr>
<td>Ciliates</td>
<td>2,334 b</td>
<td>266 a</td>
<td>112 a</td>
</tr>
</tbody>
</table>

* Bird and Smith, 2013*
<table>
<thead>
<tr>
<th>O Horizon</th>
<th>Organic</th>
<th></th>
<th>Conventional</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 15 cm</td>
<td>258,344</td>
<td>T-test 0.002</td>
<td>21,235</td>
<td></td>
</tr>
<tr>
<td>depth</td>
<td>6,991</td>
<td>T-test 0.445</td>
<td>4,524</td>
<td></td>
</tr>
<tr>
<td>15 to 30 cm</td>
<td>2,342</td>
<td>T-test 0.776</td>
<td>2,928</td>
<td></td>
</tr>
</tbody>
</table>

Bird and Smith, 2013
O-Horizon (Litter Layer)

How Does This Work?
Nematodes associated with the A horizons of three ecosystems (0-15 cm soil depth).

<table>
<thead>
<tr>
<th>Ecosystem</th>
<th>Bacterivores</th>
<th>Fungivores</th>
<th>Herbivores</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Carrots (seventeen years of certification)</td>
<td>39 b</td>
<td>97 ab</td>
<td>5 b</td>
<td>224 b</td>
</tr>
<tr>
<td>Adjacent woodlot</td>
<td>531 a</td>
<td>118 a</td>
<td>302 a</td>
<td>1121 a</td>
</tr>
<tr>
<td>Adjacent conventional corn field</td>
<td>81 b</td>
<td>34 b</td>
<td>249 a</td>
<td>421 b</td>
</tr>
<tr>
<td>P statistic</td>
<td>0.001</td>
<td>0.051</td>
<td>0.002</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Smith, 2004
Soil Health, Vineyard Health, High Quality Grapes and Good Wine:

It’s All About Balance!
Sparty Says: “Do Your 2016 Soil Health Reading Homework!”
2016 Soil Health Readings

Fundamental References

• Lehman et al. 2015. Understanding and Enhancing Soil Biological Health; Sustainability 7:988-1027.

General References

• Ingham, E. et al. 2000. Soil Biology Primer (Revised ed.).
Thanks for Listening

Professor Bird (George)