Soil Health Biology
2014 IPM Academy

George W. Bird, Professor
Michigan State University

*If the grower knows why, he will teach himself how.*
Liberty Hyde Bailey, 1916, The Principles of Fruit Growing
Nature of Soil

- Regenerative living ecosystem
- Place where energy and matter are transformed and transported.
- Foundation of healthy plant populations and communities.
Healthy Soil

- Resists Degradation
- Responds to Management in a Predictable Manner
Healthy Soil

• Key Physical Components
  – Water Stable Aggregates (%)
  – Water Holding Capacity (g/g)
  – Surface Hardness (psi)
  – Subsurface Hardness (psi)
Healthy Soil

• Key Biological Components
  – Soil Organic Matter (%)
  – Carbon Mineralization Potential
  – Nitrogen Mineralization Potential
  – Root Health
Healthy Soil

- Key Chemical Components
  - pH
  - Extractable Phosphorus
  - Extractable Potassium
  - Minor Elements
Healthy Soil

• Key Physical Components
  – Water Stable Aggregates (%)
    • Integrates, the physical, biological parameters and resolves surface and subsurface hardness issues.
  – Water Holding Capacity (g/g)
    • Role of Soil Organic Matter
Healthy Soil

• Key Biological Components
  – Soil Organic Matter (three types)
    • Decomposition Process and Organic Amendments
  – Carbon/Nitrogen Mineralization Potential and Root Health
    • Soil-Borne Organism Mediated
Decomposition/Immobilization

- Bacteria
  - Soft tissues

- Fungi
  - Cell walls
    - Cellulose
    - Hemicellulose

- Actinomycetes
  - Lignins
Processes of Nutrient Mineralization and Fixation

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
Role of nematodes, flagellates, ciliates and amoebae in nutrient mineralization

Shoot System

Root System

Energy → CO₂ → Shoot System

H₂O → Nutrients → Root System

NH₄⁺ → NH₃ → Sugar Exudate

NO₃⁻ → Sugar Exudate

Nematode C:N 10:1

Bacteria C:N 5:1

Bird, 2011
Healthy Soil

• Key Chemical Components
  – pH
  – Extractable Phosphorus
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## Impact of Management on Soil and Plant Productivity

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Soil + Management $\rightarrow$ Patterns of Soil Health and Cherry Productivity
Vertical distribution and population density of nematodes associated with eight tart cherry orchards in northern Michigan (Bird and Smith, 2013).

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<tr>
<th>Depth</th>
<th>Bacterivores</th>
<th>Herbivores</th>
<th>Fungivores</th>
<th>Omnivores</th>
<th>Carnivores</th>
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<td>Surface litter</td>
<td>1,374 b</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>0 to 6” depth</td>
<td>34 a</td>
<td>29 a</td>
<td>15 a</td>
<td>18 b</td>
<td>11 a</td>
</tr>
<tr>
<td>6 to 12” depth</td>
<td>94 a</td>
<td>17 a</td>
<td>82 b</td>
<td>24 a</td>
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Nematodes/100 cm³ soil or litter.
Vertical distribution and population density of organisms associated with eight cherry orchards in northern Michigan (Bird and Smith, 2013).
Vertical distribution and population density of organisms associated with four organic and four conventional cherry orchards in northern Michigan.

Flagellates

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<th>Depth</th>
<th>Organic</th>
<th>Conventional</th>
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<tr>
<td>Surface litter</td>
<td>258,344</td>
<td>21,235</td>
</tr>
<tr>
<td>0 to 6” depth</td>
<td>6,991</td>
<td>4,524</td>
</tr>
<tr>
<td>6 to 12” depth</td>
<td>2,342</td>
<td>2,928</td>
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T-test: 0.002, 0.445, 0.776

Bird and Smith, 2013
Three Phases of Complex, Open, Non-Linear Systems

• Development
  – Plant Establishment

• Dynamic Equilibrium
  – Optimal Years

• Senescence
  – Declining Plant
Management Tips

• Minimize physical soil disturbance.
• Keep fungicide, insecticide, nematicide and herbicide soil applications to a minimum.
• Optimize soil organic matter (cover crops, mulch etc.).
• Enhance beneficial soil-borne organism populations (compost).
• Pulse the soil for timing of nutrient mineralization (water/compost tea etc.)
Recent Soil Health Initiatives

1. On May 16, 2012, the Michigan Potato Industry Commission today released a new “white paper” on soil health
   - It states that soil health is a critical factor in optimizing crop productivity, not only in the potato industry but in all commodities.
   - The document contains a three phase plan of action, including a soil health survey using the Cornell University Soil Health Protocol.

2. In 2012, North Dakota State University, with assistance from the North Dakota corn growers, filled three new faculty position in the area of soil health.

3. In 2013, Washington State tree fruit growers just endowed a Soil Health Professorship at Washington State University

4. My new alternate e-address is soilhealthbiology@gmail.com.
Take-Home Message

- System Regulators
  - Management and Biology

- System Responses
  - Crop Productivity and Soil Health

- Be Patient
  - A Healthy Soil Takes Time

- Remember Your Friends
  - They will Take Care of You

Soil + Management $\rightarrow$ Patterns of Soil Health/Productivity
In Conclusion,

Every decision a farmer makes for his operation affects its ecology (Harwood, 2010).
Sparty Says: “Do Your Soil Health Homework”!
Soil Health Readings
G. W. Bird, Michigan State University (2014)

Fundamental References


General References