Fundamental Concepts in Organic Agriculture

Soil Fertility Workshop
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Outline

• Definition
• Historical Development and Philosophy
• Principles
• Nutrient Cycles - Soil Biology
• Tools and Practices
“..an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony.”

National Organic Standards Board
Origins

- J.I. Rodale coined the word “organic” (1940’s) and principal figure in U.S. organic agriculture.
- Rodale’s concepts drawn primarily from British agronomists Albert Howard
  - “An Agricultural Testament” (1943)
  - “The Soil and Health” (1947)
    - Natural approach to building soil fertility, return wastes to the soil
- Lady Eve Balfour, “The Living Soil” (1948)
  - Ecological farming
- Rachel Carson, “Silent Spring” (1962)
Philosophy

- Human health tied to the health of the environment
- A healthy soil is the foundation
- “Feed the soil to feed the plant”

Guiding Principles

- **Biodiversity**
  - Mimic nature, improve nutrient cycling, disease suppression, tilth, and N fixation

- **Diversification and Integration**
  - Integrating crop and livestock operations
  - Perennial and annual cropping systems

- **Sustainability**
  - Reduce off-farm inputs
  - Enhance soil resource

- **Natural Plant Nutrition**
Guiding Principles

● Natural Plant Nutrition
  - Manage nutrients by managing soil organisms
  - Build the soil

● Natural Pest Management
  - Pests are indicators of “...how far a system has strayed from the natural ecosystem it seeks to imitate.”
  - Natural predators and the maintenance of a complex agro ecosystem

● Integrity
  - Protecting organic products from contamination and commingling with non-organic products
Feed the Soil?

Feed the bugs!
- Microorganisms
  - Bacteria
  - Fungi
  - Actinomycetes
  - Protozoa
  - Algae
- Nematodes
- Macrofauna
  - Earthworms

“The plow is one of the most ancient and most valuable of man’s inventions; but long before he existed the land was in fact regularly ploughed, and continues to be thus ploughed by earthworms.”

Charles Darwin, 1881
Nutrient Cycling

- Soil microorganisms mediate nutrient cycles through decomposition of organic residues
  - Microorganisms ‘feed’ on the residues
  - Biochemical by-products are plant nutrients (N,P,S) and other beneficial compounds like humic acid

- Mineralization
  - Microbial conversion of organic N, P, and S into ammonium, phosphate, and sulfate
  - Nutrients become available

- Immobilization
  - Microbial assimilation of inorganic N, P, and S
  - Nutrients temporarily tied up in microbial biomass
Mineralization/Immobilization

C:N ratio > 25-30
net immobilization
N deficiency

C:N ratio < 25
net mineralization
Source of plant N

Factors Affecting Mineralization

1. Temperature

- Reaction rates double with every 10°C increase

De Neve et al., 2002
Factors Affecting Mineralization

2. Moisture
   - Mineralization low under dry conditions
   - Increase to optimum under moist conditions
   - Decrease as soil becomes saturated

Source: Cassman & Munns, 1980
Microbial Functional Groups

- **Bacteria**
  - decomposers, primary players in NP and S cycling
  - Actinomycetes act on more complex compounds to form humus

- **Fungi**
  - Decomposers, attack lignin
  - Nutrient acquisition (mycorrhiza)

- **Protozoa and Nematodes**
  - Consume bacteria and fungi releasing plant nutrients (N)
  - Activity increases decomposition rates
Factors Affecting Microbial Populations

- **Moisture**
  - Microorganisms need water to survive

- **Oxygen**
  - Bacteria both aerobic and anaerobic
  - Fungi, protozoa and nematodes aerobic

- **Temperature**
  - Adaptable
  - Activity generally increases as temperature rises

- **Soil pH**
  - Bacteria sensitive to acidity
  - Fungi function at low pH

- **Organic Matter**
  - OM source of C and nutrients
  - OM additions stimulate microbial growth
Agricultural Practices Affecting Microbial Populations

- **Tillage**
  - Destroys fungi, meso and macrofauna
  - Reduces OM
  - Reduces aggregation

- **Fertilizers**
  - N and P fertilizers create acid zones killing microorganisms

- **Fumigation**
  - Indiscriminant destruction of microbial community

- **Monocropping**
  - Reduces microbial diversity
  - Promotes pest build-up
What About the Soil Food Web?

http://www.magicsoil.com/MSREV2/soil_food_web.htm
What About the Soil Food Web?

- Important to recognize the role of each functional group and their interdependence
- Remember that management practices affect microbial interactions
- Soil tests to quantify soil food web are expensive and difficult to interpret
- Hot area for research
Tools and Practices

Crop Rotation

- Soil fertility
  - Legumes for N fixation
  - Diverse rooting habits

- Pest Management
  - Break pest cycles
  - Promote diversity

- Know the family of the crops

- Crops rotated so that crops from different families follow each other

Diagram:
- Lettuce
- Tomatoes
- Beans
- Corn
Tools and Practices

Crop Rotation

- Crops rotated so that crops from different families follow each other

Example

Lettuce → Beans → Corn → Tomatoes
Tools and Practices

Green Manures in the Crop Rotation:

- **Soil fertility**
  - Legumes for N fixation
  - Grasses for OM accumulation
  - Diverse rooting habits

- **Pest Management**
  - Break pest cycles
  - Promote diversity, attract beneficials
  - Biofumigants (brassicas, sudan grass, sunn hemp)

- **Weed Management**
  - Perennial rye
  - Oats
Tools and Practices

Composts and Manures:

- **Soil Conditioner**
  - Feed the soil
  - Improve physical properties

- **Nutrient Availability**
  - C:N ratio
  - Total N content
  - \( \approx 15\% \) of total N in mature composts available in the first year (Bettina et al., 2003)
  - Field trials estimate that composts alone can satisfy crop N demands after 40-80 years

<table>
<thead>
<tr>
<th></th>
<th>Feather meal</th>
<th>Dairy Manure</th>
<th>Compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>C:N ratio:</td>
<td>3.2</td>
<td>18</td>
<td>10-17</td>
</tr>
<tr>
<td>Total N</td>
<td>12%</td>
<td>2.0%</td>
<td>1.0%</td>
</tr>
</tbody>
</table>
Tools and Practices

Composts and Manures:

- Timing
  - Continuous additions to build up SOM
  - Mineralization potential of soil increases as OM inputs increase with time
  - SOM acts as nutrient reserve continuously releasing nutrients
  - High N materials can be used as a rapid source of N in the short term
Tools and Practices

Intercropping and Companion Planting:

- Interplanting 2 or more mutually beneficial plants to increase biodiversity

http://oregonstate.edu/dept/ncs/photos.html
Tools and Practices

Biological Pest Control:
- Depends on managing beneficial insect predators/parasites
- Seen as default benefit of organic soil management practices that promote above and below ground diversity
- Can include the release of control agents
- Farmscaping: long/short term design to create habitats for beneficials
Tools and Practices

Tillage and Cultivation:

- Tools for weed control, residue management, manure incorporation, hardpan destruction, pest control

- Negative impacts:
  - Costly
  - Destroy humus reserves and soil organisms
  - Compaction

- Conservation and ridge tillage
  - Organic growers pioneers
Tools and Practices

**Mulching:**

- Weed control, moisture and temperature control, soil organic matter
- Large quantities of resistant organic materials (wood chips, straw, etc...)
- Not practical on a large scale
Summary

- The farm as an agro ecosystem
  - Balance through diversity
  - Crop and soil management based on understanding of interactions within the ecosystem
  - Maximum yields not always the driving force

- Careful management of soil organic matter the foundation to balance

- Shift approach from treating the symptom to managing the system and all its components
Extension’s Role in Assisting Organic Growers

- Understand and appreciate the fundamental approach
- Understand that organic farming operates on the same scientific principles governing any agricultural system
- Apply scientific principles within the agro ecological model embraced by many organic farmers
Soil and Tissue Testing for Organic Systems

- Soil and tissue nutrient concentrations relevant for both conventional and organic systems.

- Plant nutrient availability governed by the same chemical and biological reactions regardless of farming systems.
Remember the Important Role of Organic Matter in Soils

- Physical
  - Improves aggregation (glue)
  - Improves water holding capacity (surface area)

- Chemical
  - Increases nutrient availability (cycling, P and micronutrient solubility)
  - Increases CEC (200 cmol\(_c\) kg\(^{-1}\))
  - Buffers the soil against pH changes

- Biological
  - Increases microbial diversity
  - Assists in pathogen suppression
Remember the Important Role of Organic Matter in Soils

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Measuring Management Impacts on Soil Organic Matter

- **Total C**
  - Total C changes slow
  - 0.001 to 0.01% increase in SOM for every ton/a
- **Soluble C**
  - Hot water soluble C sensitive to organic inputs
- **CEC**
  - Small increases in soil C have significant impacts on CEC
- **Microbial biomass**
  - Difficult procedure sensitive to climate and other environmental factors
- **Functional Groups**
  - Expensive
  - Changes due to organic inputs or other factors?
Making Fertilizer Recommendations in Organic Systems

- Determine crop rotation
- Get soil analysis
  - Same rules apply for pH, exchangeable cations and soil P
  - Interpreting total C and total N is difficult
  - 1-5% of N in SOM mineralized (12 - 60 lbs N/a)
  - Soils receiving lots of OM may have higher N mineralization
- Obtain organic amendment chemical properties
  - C:N ratio
  - Total N
Table 1. Common organic fertilizer materials and their approximate analysis (dry weight basis).

<table>
<thead>
<tr>
<th>Material</th>
<th>Nitrogen (N)</th>
<th>Phosphorus (P)</th>
<th>Potassium (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fish meal or powder</td>
<td>10–11</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Chicken manure</td>
<td>2–3</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Processed liquid fish residues</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Feather meal</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Seabird and bat guano</td>
<td>9–12</td>
<td>3–8</td>
<td>1–2</td>
</tr>
<tr>
<td>Alfalfa meal</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cottonseed meal</td>
<td>6</td>
<td>0.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>7</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Bone meal</td>
<td>2</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Kelp</td>
<td>&lt;1</td>
<td>0</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>N</th>
<th>P</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>S</th>
<th>Fe</th>
<th>Mn</th>
<th>Zn</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry (broiler) manure</td>
<td>4.4</td>
<td>2.1</td>
<td>2.6</td>
<td>2.3</td>
<td>1.0</td>
<td>0.6</td>
<td>1000</td>
<td>413</td>
<td>480</td>
<td>172</td>
</tr>
<tr>
<td>Composted chicken (layer) manure</td>
<td>2.3</td>
<td>3.5</td>
<td>2.9</td>
<td>15.5</td>
<td>1.3</td>
<td></td>
<td>1800</td>
<td>165</td>
<td>165</td>
<td>30</td>
</tr>
<tr>
<td>Dairy cow manure</td>
<td>2.4</td>
<td>0.7</td>
<td>2.1</td>
<td>1.4</td>
<td>0.8</td>
<td>0.3</td>
<td>1100</td>
<td>182</td>
<td>390</td>
<td>150</td>
</tr>
<tr>
<td>Swine manure</td>
<td>2.1</td>
<td>0.8</td>
<td>1.2</td>
<td>1.6</td>
<td>0.3</td>
<td>0.3</td>
<td>-</td>
<td>150</td>
<td>175</td>
<td>30</td>
</tr>
<tr>
<td>Sheep manure</td>
<td>3.5</td>
<td>0.6</td>
<td>1.0</td>
<td>0.5</td>
<td>0.2</td>
<td>0.2</td>
<td>-</td>
<td>200</td>
<td>125</td>
<td>25</td>
</tr>
<tr>
<td>Horse manure</td>
<td>1.4</td>
<td>0.4</td>
<td>1.0</td>
<td>1.6</td>
<td>0.6</td>
<td>0.3</td>
<td>-</td>
<td>200</td>
<td>125</td>
<td>25</td>
</tr>
<tr>
<td>Feedlot cattle manure</td>
<td>1.9</td>
<td>0.7</td>
<td>2.0</td>
<td>1.3</td>
<td>0.7</td>
<td>0.5</td>
<td>5000</td>
<td>40</td>
<td>8</td>
<td>2</td>
</tr>
</tbody>
</table>

Hue & Silva, 2000
N Mineralization and Crop Nutrition

Source: Pang & Letey, 2000
Calculating Amendment Rate

Material: Blood meal (13% N)
Crop N requirement: 150 lbs/a
N release: High N content - rapid release (80% available during the cropping system)
Calculation: $150 \text{ lbs} / (0.13 \times 0.8) = 1,442 \text{ lbs/acre}$

Material: Chicken manure (3.0% N)
Crop N requirement: 150 lbs/a
N release: moderate N content - moderate release (50% available during the cropping system)
Calculation: $150 \text{ lbs} / (0.03 \times 0.5) = 10,000 \text{ lbs/acre}$
Nutrient Additions

**P Inputs:**
- 3.5% P
- \((0.035 \times 10,000\text{lb}) = 350 \text{ lb P per acre}\)
- Assume 40-50% of total P mineralizes
- Can lead to P accumulation

**K Inputs**
- Assume 90% of the K available
- \((0.9 \times 0.021 \times 10,000\text{lb}) = 189 \text{ lb K per acre}\)
**Manure Application**

- Manure composed of Ammonia (10-30%) and organic N
- Manure should be incorporated
  - 25% NH$_3$ lost to volatilization after 1 day
  - 75% NH$_3$ lost after a week
Information Gaps

- Nutrient release form organic amendments
- Impact of green manure crops
  - Nutrients
  - Soil pathogens
  - weeds
- Impact of soil management on pest/diseases
Next Steps

- More Interaction with organic growers
- Incorporate lessons from the Mainland and Europe
- A systems approach to research integrating soils, crops, plant pathology, entomology, and weeds
Resources

Books:
Gershuny, G. and J. Smillie. The Soul of Soil
Lampkin, N. Organic Farming
Coleman, E. The New Organic Grower

Web:
http://www.attra.org/organic.html