Outline

- What are the farmers goals/needs for their soil? (Brian and Elsa) 5 min
- Nutrient building (Elsa) 20 min
- Soil tests and recommendations (Brian and Elsa) 5 min
- Nutrients and weeds (Brian) 10 min
- N from cover crops/green manures (Brian) 10 min
- Case studies (Brian and Elsa) 10 min

Farmer Goals/Needs for their Soil

- Production
- Sustainability (physical, biological, economic)
- Reduce off farm pollution
- Also--??

Compost

- Difficulty using conventional soil tests
- Excess nutrients – P, K, Mg, Ca – but many didn’t realize it
- Compost applied based on amount on hand vs. calculating
- Compost generally not analyzed prior to use

Other Support

Case study of 11 organic farms:
Those relying on compost, often had surplus nutrients, as much as about 160 – 182 lbs P & N/acre/yr excess.
Drinkwater et al., 2005

West Virginia organic research fields had begun to saturate soil nutrient holding capacity; decided to “restrict compost applications to crops with maximum yield response.”
Kotoon, 2004

Over 2 years, Morris et al., (2004) sampled 30 farms, found on average: 42% had above optimum P levels, 20% below optimum.

Challenges Using Compost

1. Compost, manures, other organic amendments & green manures slowly release nutrients
   - When & how much to apply challenging

2. Nutrient availability often unpredictable – especially nitrogen
   - When & how much to apply challenging
Mineralization

- Breakdown of organic nutrient sources
- Conversion to inorganic, plant available forms
- Rate and timing of mineralization depends on many variables
  - Soil temperature
  - Soil moisture
  - Incorporation/depth of incorporation
  - Soil microorganisms
  - Carbon to nitrogen ratio
  - Particle size
- 10-50% a year

Mineralization Process

- Fungi, bacteria, yeasts, actinomycetes, some small critters (nematodes, rotifers)
- Nitrogen temporarily tied up by microbes

C:N Ratios

- Ratio of carbon to nitrogen in a material
- C:N ratios decrease as organic material decomposes (CO₂ given off, nitrogen incorporated into fungi & bacteria)
- C:N ratio & nitrogen availability
  - > 30:1; nitrogen tied-up by microorganisms
  - < 20:1; nitrogen release

Nutrient Build Up in Soils

- Because mineralization unpredictable & uncontrollable:
  - Nutrients released at times when plant need is not high resulting in build up of nutrients & salts in soil
  - Organic nutrient sources are often over applied to insure nitrogen available for good crop yields

Nutrient Build Up

- Also, organic nutrient sources often contain more than one nutrient, not in balance with crop needs resulting in surpluses
- Compost 1 – 0.7 – 1
  - Applied 12.5 tons/acre
  - 250 lbs nitrogen; 175 lbs P₂O₅; 250 lbs K₂O
Compost Use for High Tunnel Bell Peppers

• 10-wk-old ‘Paladin’ in 2000, ‘King Arthur’ in 2001 transplanted late May
• 4 Raised beds per tunnel; 18” in row spacing
• Drip irrigation
• Harvest mid July – late Oct.
• Pests: weeds – hand weeded; aphids – ladybird beetles

Compost Treatments

• Compost – dairy manure based
• 3 treatments compost applied at 1” or 2” depth, incorporated 12”; inorganic fertilizer at a rate of 75-150-75

Nutrient Recommendations

• Clay-loam soil, nutrients in optimum range
• Nitrogen – 100 lb/acre
• Phosphate – 150 lb/acre
• Potash – 100 lb/acre

Beginning Soil Analysis

<table>
<thead>
<tr>
<th>Soil Property</th>
<th>lb/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>P₂O₅</td>
<td>174 ± 44</td>
</tr>
<tr>
<td>K₂O</td>
<td>383 ± 66</td>
</tr>
<tr>
<td>CaO</td>
<td>3862 ± 565</td>
</tr>
<tr>
<td>MgO</td>
<td>356 ± 63</td>
</tr>
<tr>
<td>pH</td>
<td>6.7 ± 0.2</td>
</tr>
<tr>
<td>Organic matter (%)</td>
<td>2.4 ± 0.3</td>
</tr>
<tr>
<td>Soluble salts (mmhos/cm)</td>
<td>0.15 ± 0.03</td>
</tr>
</tbody>
</table>

Compost Properties

<table>
<thead>
<tr>
<th>Soil Property</th>
<th>lb/ton FW</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>33</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>15</td>
</tr>
<tr>
<td>K₂O</td>
<td>17</td>
</tr>
<tr>
<td>Ca</td>
<td>117</td>
</tr>
<tr>
<td>Mg</td>
<td>28</td>
</tr>
<tr>
<td>pH</td>
<td>8</td>
</tr>
<tr>
<td>C:N</td>
<td>12</td>
</tr>
<tr>
<td>Soluble salts (mmhos/cm)</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Available Nutrients Added

<table>
<thead>
<tr>
<th>Fertilizer</th>
<th>lb/acre</th>
<th>1”</th>
<th>2”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>75</td>
<td>441*</td>
<td>883*</td>
</tr>
<tr>
<td>Phosphate</td>
<td>150</td>
<td>1345</td>
<td>2683</td>
</tr>
<tr>
<td>Potash</td>
<td>75</td>
<td>1559</td>
<td>3118</td>
</tr>
<tr>
<td>Calcium</td>
<td>0</td>
<td>10570</td>
<td>21147</td>
</tr>
<tr>
<td>Magnesium</td>
<td>0</td>
<td>2555</td>
<td>5110</td>
</tr>
</tbody>
</table>

*using a 15% mineralization rate
Nutrient Summary

- Nitrogen
  - 1" compost = 4.5x more than 100 lbs/a
  - 2" compost = 9x more
- Phosphate
  - 1" compost + soil = 10x more than 150 lbs/a
  - 2" compost + soil = 19x
- Potash
  - 1" compost + soil = 13x more than 100 lbs/a
  - 2" compost + soil = 35x

Marketable Pepper Yield

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilizer</td>
<td>2.1</td>
<td>3.3</td>
</tr>
<tr>
<td>1&quot; Compost</td>
<td>2.4</td>
<td>3.3</td>
</tr>
<tr>
<td>2&quot; Compost</td>
<td>1.4</td>
<td>2.9</td>
</tr>
</tbody>
</table>

Soil Properties After Harvest

<table>
<thead>
<tr>
<th></th>
<th>Fertilizer</th>
<th>1&quot; Compost</th>
<th>2&quot; Compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 pH</td>
<td>6.4</td>
<td>7.3</td>
<td>7.4</td>
</tr>
<tr>
<td>OM (%)</td>
<td>2.5</td>
<td>4.8</td>
<td>6.6</td>
</tr>
<tr>
<td>Salts (mmhos/cm)</td>
<td>0.14</td>
<td>0.45</td>
<td>0.81</td>
</tr>
<tr>
<td>2001 pH</td>
<td>6.8</td>
<td>7.3</td>
<td>7.3</td>
</tr>
<tr>
<td>OM (%)</td>
<td>2.3</td>
<td>4.7</td>
<td>6.6</td>
</tr>
<tr>
<td>Salts (mmhos/cm)</td>
<td>0.30</td>
<td>0.95</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Conclusions

- Possible salt injury led to lower yields
  - 0.40 or 1.5 mmho/cm threshold for peppers
  - Above threshold 16-50% yield reduction
- Exclude precipitation and drip irrigation
- Leaching reduced; can lead to build up of salts

Using Compost

- Nutrient content varies; recommend tested to determine amount of nutrients
- Apply nutrients based on plant needs vs. volume
- Leaching in soil or compost - remove plastic, sprinkler irrigation

Problems with Over-Application

- Loss profits due to cost of over-applied organic nutrient sources
- Indirect losses from decreased yields associated with high salt or nutrient levels in soil & weed competition
- Pollution of surface & groundwater
How to Avoid Over Application

- Soil testing
- Analyze compost
- Calculate how much to apply
- Use variety of nutrient sources
- Avoid continuous use of any single organic nutrient source with more than 1 nutrient

3 Composts

<table>
<thead>
<tr>
<th>Soil Property</th>
<th>Compost 1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic N (%)</td>
<td>1.1</td>
<td>1.2</td>
<td>0.7</td>
</tr>
<tr>
<td>NH₄⁺-N (lb/ton)</td>
<td>1.6</td>
<td>1.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Phosphate (%)</td>
<td>0.5</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Potash (%)</td>
<td>0.8</td>
<td>1.8</td>
<td>0.4</td>
</tr>
<tr>
<td>pH</td>
<td>7.4</td>
<td>6.9</td>
<td>7.5</td>
</tr>
<tr>
<td>C:N</td>
<td>12.1</td>
<td>13.2</td>
<td>14.7</td>
</tr>
<tr>
<td>Soluble salts (mmhos/cm)</td>
<td>5.5</td>
<td>14.1</td>
<td>0.8</td>
</tr>
</tbody>
</table>

75 lb/acre N

- Compost 1
  - 12.5 tons/acre (55 lbs organic N + 20 lbs ammonium-N)
- Compost 2
  - 12 tons/acre
- Compost 3
  - 27 tons/acre

When Nutrient Levels are High

- Soil testing to monitor levels
- Nitrogen supply – use N sources with no or minimal levels of other nutrients
  - Legume cover crops, other nutrient sources
  - Calculate residual nitrogen to determine how much is needed
- Plant cover crop, reduce tillage, use grass waterways to minimize erosion, runoff losses

How to Avoid Over Application

- For organic nutrient sources with more than 1 nutrient
  - Use only when soil P, K levels not above optimum (exception, P in cold soils)
  - If P, K levels high, use legume cover crops, nitrogen fertilizers with no or low levels of P & K
  - Always incorporate to minimize runoff & erosion losses

Soil tests and recommendations

- Variety of tests and philosophies
- Early years—more intensive sampling
- After about 5 years—sampling to monitor the fertility program, every 2-3 years
Nutrients and Weeds

- Recent research results

The problem

- Most livestock farms and organic farms use compost and manure as primary nutrient sources
- Correct application rates are difficult to determine
  - Nutrients released slowly over time
  - Concentration varies
- Farmers often err on the high side to ensure adequate nutrients for crop growth
- Enough to supply N needs usually applies excess P and K

Crop yield responses to compost

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
<th>Soluble</th>
<th>High OM</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>Corn</td>
<td>0.5X</td>
<td>0.67X</td>
</tr>
<tr>
<td>2005</td>
<td>Soybean</td>
<td>No response</td>
<td>No response</td>
</tr>
<tr>
<td>2006</td>
<td>Spelt</td>
<td>0.8X</td>
<td>2.0X</td>
</tr>
<tr>
<td>2007</td>
<td>Corn</td>
<td>No response</td>
<td>No response</td>
</tr>
</tbody>
</table>

Cornell Organic Cropping Systems: Grain Experiment

- Initiated 2005
- 3-year rotation: soybean → spelt/(red clover) → corn
- 5 Systems
  - “High” nutrient
  - Low input
  - Intensive weed management
  - Reduced tillage
  - Chemical
Weed dry weight in corn, 2010

Which nutrient is limiting for the weeds?
- The answer determines the management strategy.
- 2010 Experiment
- Alfalfa/clover plow down on low K, low P soil

Pigweed biomass
- Pigweed Control
- Pigweed with highest rate of compost
- Pigweed with highest "N-P-K" treatment

Corn Control
- Corn at highest compost rate

N from Cover Crops and Green Manures

Error bars are standard error.
Balancing Cover Crops and Tillage

- Tillage destroys soil organic matter
- How to balance planting a cover crop which may require extra tillage?
- Get the most out of it

Spring Oats and Peas

- Plant as early as possible
- Terminate in early July before fall-planted brassicas
- Good biomass production
- 5000 lb/acre peas – 150 lb/acre N
- Good weed suppression

Summer Oats and Peas

- Plant before 8/15
- Allow to winter kill
- Moderate biomass production
- 3000 lb/acre peas – 100 lb/acre N
- Good weed suppression

Red Clover

- Production of 1000-4000 lb/acre of dry biomass in the fall
- Plus 2500-5000 lb/acre by plowdown (mid May) the following spring
- Roots are substantial as well
- Adequate N for 160 bu/acre corn on a strong soil
Hairy Vetch—Early Fall
- Planting date not critical if before 9/15
- Can plant with a grass companion crop
- 5000 lb/acre biomass – 150+ lb/acre N

Rye can inhibit crop growth
- Managing for maximum biomass is good if residues are to be harvested (for mulch) or left on the surface
- If tilled in, they can strongly inhibit crop growth
  - Sucking all the moisture out of the soil
  - Tying up N
  - Allelopathy (roots also?)
- To prevent this, till under in early May when the tissues are green and lush
- Planting with hairy vetch will add more N

<table>
<thead>
<tr>
<th>Cover crop</th>
<th>Planting Window</th>
<th>Termination Window</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hairy Vetch</td>
<td>Before 9/15</td>
<td>After 5/15</td>
<td>Terminating in June is much better</td>
</tr>
<tr>
<td>Austrian Winter Peas</td>
<td>8/1 to 9/15</td>
<td>After 5/15</td>
<td>Terminating in June is much better</td>
</tr>
<tr>
<td>Field Peas and Oats—Spring</td>
<td>April</td>
<td>July</td>
<td>They should grow for at least 75 days; use forage varieties</td>
</tr>
<tr>
<td>Field Peas and Oats—Later Summer</td>
<td>Before 8/15</td>
<td>Winterkill</td>
<td>A dramatic decrease in biomass after mid-August (50% in 10 days)</td>
</tr>
<tr>
<td>Rye</td>
<td>Before 9/15</td>
<td>Late May</td>
<td>Best with hairy vetch; if incorporated, terminate earlier</td>
</tr>
<tr>
<td>Red Clover</td>
<td>Frost seed into winter grain</td>
<td>May of following year</td>
<td>Excellent rotational strategy</td>
</tr>
<tr>
<td>Buckwheat</td>
<td>June and July</td>
<td>40 days after planting</td>
<td>Do not wait to terminate; may produce seed</td>
</tr>
</tbody>
</table>

Making Legumes Work Harder
- Legumes get lazy and fix less N in a high N environment (it takes energy to feed the Rhizobium bacteria that fix the N)
- Planting with a grass companion can help
- If soil is already high in N, use lower grass seeding rate
- This may also help slow down the release of legume N, making it better timed to crop needs
What do we know about root systems?

- Not much
- Roots are woodier and decompose slower than plant tops
- Some researchers think that the main benefit from cover crops derives from their roots
- Root biomass is often in the range of 30% of aboveground for annuals
- Perennials like clover may have much larger relative root biomass

More sources of information

- Thomas Bjorkman at Cornell has created a clearinghouse of CC information
  - [http://www.hort.cornell.edu/bjorkman/lab/covercrops/](http://www.hort.cornell.edu/bjorkman/lab/covercrops/)
- Managing Cover Crops Profitably, 3rd Ed.
- Others?

Case Studies

- Nutrient budgets
- Blue Heron Farm, Lodi, NY
- Paradise Farm, Paradise, PA

Nutrient Budgets, 11 Farms

![Nutrient Budgets, 11 Farms](Image)
Table 2. Soil Test Results for Blue Heron Farm, 1993 and 1999, analyzed by Cornell University. Mean (with standard error) of 10 fields.

<table>
<thead>
<tr>
<th></th>
<th>1st Barn 1993</th>
<th>1st Barn 1999</th>
<th>Vineyard 1993</th>
<th>Vineyard 1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus (lb/acre)</td>
<td>62</td>
<td>436</td>
<td>29</td>
<td>425</td>
</tr>
<tr>
<td>Potassium (lb/acre)</td>
<td>400</td>
<td>875</td>
<td>285</td>
<td>435</td>
</tr>
<tr>
<td>Magnesium (lb/acre)</td>
<td>415</td>
<td>850</td>
<td>260</td>
<td>450</td>
</tr>
<tr>
<td>Calcium (lb/acre)</td>
<td>4140</td>
<td>8360</td>
<td>2980</td>
<td>4420</td>
</tr>
<tr>
<td>pH</td>
<td>7.4</td>
<td>7.1</td>
<td>7.1</td>
<td>7.4</td>
</tr>
<tr>
<td>Percent Organic Matter</td>
<td>4.4</td>
<td>4.9</td>
<td>2.7</td>
<td>2.7</td>
</tr>
</tbody>
</table>
Figure 2. Cumulative nutrient balances for N, P, and K for five years of a typical rotation on Paradise Farm.