Soil Health

Where: Grand Gallery (main level) Room A & B  
MI Recertification credits: 2 (COMM CORE, PRIV CORE)  
CCA Credits: SW(2.0)  
Moderator: Hal Hudson, Extension Educator, Tuscola Co. MSU Extension

2:00 pm  Practical Ways to Assess and Manage Soil Health for Disease Control and Improved Yield  
  - George Abawi, Plant Pathology Dept., Cornell Univ. NYAES, Geneva, NY

2:45 pm  Practical Ways to Use Biofumigant Cover Crops for Soil Health Improvement  
  - Mathieu Ngouajio, Horticulture Dept., MSU

3:15 pm  Advanced Soil Organic Matter Management: Principles for a Healthy Crop  
  - Sieglinde Snapp, Plant, Soil and Microbial Sciences Dept., MSU

3:45 pm  Question and Answer

4:00 pm  Session Ends
Poor management of soils contributes to gradual degradation of soil quality and health, resulting in lower quality and quantity of marketable crop yields. Also, it is well known that root diseases and their damage are most severe in poor quality/unhealthy soils. Thus, the recent interest in the concept of soil health and the implementation of sustainable soil health management practices. Maintaining or improving the health status of soil involve a holistic approach to integrate and optimize the physical, chemical and biological properties of soil for improved crop health and productivity in a sustainable manner. The latter suggested the need to assess the soil health status of target fields in order to identify the major production constraint(s) to be addressed in any planned soil management intervention. The Cornell Soil Health Program Work Team developed a cost-effective Soil Health Assessment Protocol/Test (CSHT), which is now offered for a fee [http://soilhealth.cals.cornell.edu](http://soilhealth.cals.cornell.edu). The developed soil CSHT consists of measuring four physical, four biological and 7 chemical indicators. In addition, the textural composition of the soil sample is determined and provided in the report. The selection of the indicators was based on their sensitivity to management practices, precision of the method, relevance to important functional soil processes, ease and cost of sampling, and cost of analysis. The results of the soil health analyses of each submitted sample are presented in a visually enhanced format in the CSHT report, which is color coded to aid practitioners in targeting their management practices to identified soil health constraints. Soil sampling, measurements of selected indicators and the interpretations of results will be illustrated and discussed during the presentation.

Available soil health management practices include numerous reduced tillage systems, cropping sequences, cover cropping, and various other amendments. It is known that all of these production practices have direct and/or indirect effects on all soil properties, but only limited information is available on the impact of their numerous combinations on crop productivity and health. Results from several collaborative projects dealing with the impact of soil health management practices employed singly or in combinations on crop yield, root health and measured soil health quality indicators will be presented and discussed.

In collaboration with the Cornell soil health team, the combined effects of tillage practices (No-till/ridge-till, Zone-till, Plow-till), cover crops (Rye grain, Vetch, Fallow), and crop rotation (Vegetables vs. Grain/Forage/Vegetable) have been evaluated at the long-term soil health site (14 A) at the Gates Farm, NYSAES since 2003. In 2011, all the 72 plots were planted to snap bean cv. ‘Caprice’ to assess the accumulated effects of the tested treatments and their combinations. Results obtained in 2011 showed that pod yield of the indexing snap bean crop was highest in the ridge-till and in the zone-till plots and was lowest in the plow-till plots in both crop rotations (Table 1). In addition, it was difficult to machine harvest the plow-till plots due to excessive rainfall during the growing season (Figure 1), but there was no problem harvesting the reduced tillage plots and also the ridge-till plots. Root rot severity assessment in the field and in the
greenhouse bean bioassay did not differ greatly among the various treatments, but it was lower on roots of plants grown in the ridge-till plots. Again, the reduced tillage practices appear to improve measured soil health indicators, but final mining of the data is still in progress.

Nine cover crop treatments (rye grain + hairy vetch, oat, sudex, forage radish, red clover, rapeseed, buckwheat, wheat, and a fallow/control) were evaluated for their efficiency in reducing the severity of root diseases and improving yield under varying disease pressure and soil quality levels. Marketable yield of bean varied among the cover crop treatments and was influenced by the previous management strategies employed (four production systems tested) and also years. However, the lowest bean yields were generally in the buckwheat and the fallow check, whereas the highest yield fellowed primarily the rye/vetch, wheat, and oat. Weed pressure was least in the rye/vetch, wheat, and rapeseed plots, whereas weeds were the most severe in the fallow/check, buckwheat, and sudex plots. In addition, Buckwheat, clover and the fallow check appeared to increase root rot severity of beans in this evaluation. In contrast, the lowest accumulated increases in root rot severity over the duration of the study were in the wheat, sudex, oat, and radish plots. Many studies have shown that cover crops differ greatly in their suppression of various root pathogens (Fig. 2) as well as other soil management practices. Roots of vegetables and other crops growing in healthy soils are generally large, coarse, white, penetrate deeper into the soil, have greater number of fine fibrous rootlets, and exhibit limited or no symptoms of damage by root pathogens. Thus, such roots are more efficient in absorbing water and nutrients and will contribute to increased plant productivity. Additional examples of the impact of soil health management practices on root diseases and other pests will be presented and discussed during the presentation.

Acknowledgment: The contributions of members of the Cornell Soil Health Program work Team (especially Dr. Harold van Es and his staff) and research collaborators (especially Dr. Beth Gugino and Dr. James LaMondia) are gratefully acknowledged.
Table 1. Impact of tillage practices and crop rotations on stand establishment, root rot severity and yield on snap beans at the Soil Health Site, Gates Farm, 2011.

**Rotation 1**

<table>
<thead>
<tr>
<th>Tillage</th>
<th>#Plant/10ft</th>
<th>RRS (1-9)</th>
<th>Pod Wt Lb/100ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ridge</td>
<td>46.8</td>
<td>4.2</td>
<td>53.5</td>
</tr>
<tr>
<td>Zone-Till</td>
<td>47.5</td>
<td>4.5</td>
<td>45.1</td>
</tr>
<tr>
<td>Plow</td>
<td>46.9</td>
<td>5.3</td>
<td>29.8</td>
</tr>
<tr>
<td><strong>LSD</strong></td>
<td><strong>3.85</strong></td>
<td><strong>0.55</strong></td>
<td><strong>10.21</strong></td>
</tr>
</tbody>
</table>

**Rotation 2**

<table>
<thead>
<tr>
<th>Tillage</th>
<th>#Plant/10ft</th>
<th>RRS (1-9)</th>
<th>Pod Wt Lb/100ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-Till</td>
<td>41.2</td>
<td>4.3</td>
<td>44.5</td>
</tr>
<tr>
<td>Zone-Till</td>
<td>46.6</td>
<td>4.4</td>
<td>55.2</td>
</tr>
<tr>
<td>Plow</td>
<td>44.5</td>
<td>4.0</td>
<td>34.1</td>
</tr>
<tr>
<td><strong>LSD</strong></td>
<td><strong>4.2</strong></td>
<td><strong>0.45</strong></td>
<td><strong>11.0</strong></td>
</tr>
</tbody>
</table>
Figure 1. Photos illustrating the benefit of reduced tillage practices on soil conditions during harvest (August 2011) after excessive rainfall events. No-till and Zone-till plots are in the top photos, whereas the plow-till plots are in the lower photos.

Figure 2. Effect of selected cover crops (L to R, Oats, Rapeseed, Fallow/Check and buckwheat) on bean root-rot severity.
Practical Ways to Use Biofumigant Cover Crops for Soil Health Improvement

Mathieu Ngouajio
Associate Professor
Dept. of Horticulture
Michigan State University
East Lansing, MI 48824

Brassica cover crops have been used successfully in cropping systems as biofumigants. Brassica cover crops, including oilseed radish, brown mustard, oriental mustard, yellow mustard, turnip, rape, etc., have been shown to provide multiple benefits in cropping systems. Brassica species produce glucosinolates (sulphur containing substrates), which are secondary metabolites, used by plants to defend themselves against biotic and abiotic stresses. Glucosinolates are hydrolyzed by thioglucosidase (myrosinase) enzymes.

Within the plant, glucosinolates and myrosinase enzymes are physically separated. Glucosinolates are stored in the central vacuole while myrosinases are stored in the cytosol. Upon mechanical damage of plant tissue, insect or pathogen attack, these enzymes are released (get in contact with the glucosinolates) and trigger the breakdown reaction sometime referred to as the “mustard bomb.” Upon hydrolysis of glucosinolates by myrosinase enzymes, a number of chemicals are released, in which isothiocyanates, thiocyanates, and nitriles are known to be active and to suppress pests, including phytophagous insects, nematodes, weeds, and fungi. Because of the ability of Brassica species to produce those volatile toxic compounds Brassica cover crops are also called biofumigants. The process of breaking down Brassica tissues and incorporating them in the soil is called “biofumigation”. When managed adequately, biofumigants have helped reduce the populations of nematodes, weeds, and diseases in cropping systems. The following are practical ways to use brassica cover crop biofumigants in cropping systems and tips to help maximize their benefits.

A. Practical ways to use cover crops as biofumigants

The cropping system, cash crop growing cycle, and cash crop planting method and seed size all affect the way biofumigants are used.

1. Perennial cropping systems.
In a perennial cropping system, the cash crop is established for many years of production. Example asparagus (15-20 years of production). There are two main options for fitting biofumigants in perennial cropping systems.

   a. **Option 1: Cover crops planted prior to cash crop establishment.** For management of replant suppression problems many asparagus growers have started to use biofumigants between plantings (before establishment of a new crop). While this practice is relatively new benefits can be maximized by using more than one cycle of biofumigation.
b. **Option 2: Cover crops planted in the fall when the cash crop is going dormant.** Brassica cover crops are cool season species and can sustain acceptable growth in the fall if the seedling is well established. Preliminary studies in Michigan indicate that the cover crops can be integrated into established asparagus production fields with significant yield improvement. In the trials the cover crops were seeded between the end of July and Mid August and allow winterkilling by frost. The major constrain for this practice is to develop an adequate planter for drilling the cover crops into an established field. Also the biofumigation potential is limited by the fact that the cover crops are not incorporated into the soil.

2. **Annual cropping systems**
Annual cropping systems offer more flexibility compared to perennial cropping systems. However, the cash crop dictates how the biofumigants are used. Brassica cover crops are not recommended in rotation systems with brassica cash crops (cabbage, broccoli, ..). The length of the cash crop growing cycle, the type of seedbed and seeding method influence brassica cover crop management practices.

a. **Crops with long growing cycle.** When the cash crop has a long growing cycle that spans the entire season, the cover crop should be scheduled in the overall rotation system. Typical examples are onions and carrots. These crops are usually planted early in the spring and may not be harvested before late fall. That does not leave a window to grow brassica cover crops within the same season. In that case growers have planted the cover crops the fall prior to cash crop season. That practice has resulted in about 15% increase in onion yield in muck soils under Michigan conditions. That has also helped reduced onion seeding rate by up to 20% with no yield penalty.

b. **Crops with medium to short growing cycle.** Crops like cucumber, transplanted celery, allow adequate window early or late in the season to grow brassica cover crops. **Option 1. Early spring cover crop.** When planted early in the spring, the cover crops are incorporated into the soil in late May follow by the cash crop 2 to 3 weeks later. **Option 2. Late summer cover crop.** The cover crops are planted after harvest on an early crop like cucumber, snap bean etc. In this case the cover crops in used in preparation for a cash crop the following year (example a crop with long growing season).

c. **Direct seeded vs. transplanted crops.** A crop established with transplants offers more flexibility for use of brassica cover crops. The plant back period can be shorter since transplants are in more advanced stage of growth and are less affected by cover crop residue than germinating seeds. Direct seeded crops with small seeds like onion, and carrot require a well-prepared seedbed with low residue for adequate operation of the seeder and uniform seedling emergence and establishment. For these crops, the best results have been obtained when the cover crops were planted the previous fall.
B. Tips to help maximize benefits of cover crops used as biofumigants

Table 1. Some of the recommended practices for efficient biofumigation

<table>
<thead>
<tr>
<th>Factor</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species and cultivar selection</td>
<td>Use a species or cultivar with high glucosinolates content. Mustard cover crops vary in their glucosinolate content. Species and cultivar selection is therefore critical.</td>
</tr>
<tr>
<td>Biomass Production</td>
<td>Maximize biomass production by using appropriate seeding rate, method, and time. Keep in mind that high seeding rates may actually result in low biomass production due to intra-specific competition. It may be necessary to apply some fertilizer to boost growth. Allow the cover crops to grow to full bloom.</td>
</tr>
<tr>
<td>Tissue breakdown</td>
<td>Break down plant tissue to trigger the glucosinolate-myrosinase reaction (a flail mower will do an excellent job).</td>
</tr>
<tr>
<td>Soil moisture</td>
<td>Adequate soil moisture is critical during cover crop incorporation. Efficacy of biofumigation is reduced significantly when the cover crops are incorporated into dry soil. If necessary use overhead irrigation about 12 hours before cover crop incorporation.</td>
</tr>
<tr>
<td>Residue incorporation</td>
<td>Incorporate the residue immediately because most of the break down products are volatile. Depending on soil conditions a roto-tiller or multiple passes of a disk can be used for residue incorporation.</td>
</tr>
<tr>
<td>Soil surface sealing</td>
<td>Seal the soil surface (with irrigation or a packer if possible). In plasticulture systems, lay the plastic immediately after cover crop incorporation. The combined effects of biofumigation and anaerobic soil disinfestation may be achieved with the use of plastic mulch.</td>
</tr>
<tr>
<td>Plant back period</td>
<td>Brassica cover crop residue is toxic. Avoid planting susceptible crops shortly after Brassica cover crop incorporation. This is especially important for small seeded crop that are direct seeded. However, severe injury has been reported on transplants. Observe a cash crop plant back period of at least 2-3 weeks (depending on the crop).</td>
</tr>
</tbody>
</table>

Table 2. Some practices to avoid during biofumigation

<table>
<thead>
<tr>
<th>Factor</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid rotation with other Brassica species</td>
<td>• Brassica species do not form mychorizae. Therefore, monoculture practices could reduce mychorizae in the soil.</td>
</tr>
<tr>
<td></td>
<td>• Rotate brassica cover crops with non-brassica cover crops.</td>
</tr>
<tr>
<td></td>
<td>• Increase in cabbage maggot populations have been observed in some growing conditions after Brassica cover crops and could negatively affect brassica cash crops.</td>
</tr>
<tr>
<td></td>
<td>• Flea beetles are attracted by Brassica cover crops and may increase the risk of crop injury if Brassica cash crops are a component of the cropping system. It is noted that yellow mustards with hear-like structures, ‘Ida Gold’ being one, are less attractive to flea beetles than Oriental mustards or oilseed radish.</td>
</tr>
<tr>
<td>Avoid volunteer cover crops</td>
<td>• Viable seed formation by the cover crops could result in serious weed problems with volunteers.</td>
</tr>
<tr>
<td></td>
<td>• Drilling the cover crops (as opposed to broadcast and incorporation) will also reduce the risk of volunteers.</td>
</tr>
</tbody>
</table>
Advanced soil organic matter management –
Principles for a healthy crop

Dr. Sieg Snapp Professor of Soils and Cropping Systems, W.K. Kellogg Biological Station – MSU

How do you define soil quality?

The ability of a soil to enhance productivity, attenuate environmental contaminants, pathogens and offsite damage.

Fitness for use

'Strong yields'

Compare Soil to Natural Area

Select a natural area near your field
- Fencepost or forest edge
- Collect and test soils separately
- Compare results: natural area = soil quality goalpost

How to Build SOM

1. Increase C inputs
   - Manage residues
   - Grow cover crops
   - Add manure or compost

2. Decrease C loss – slow decomposition
   - Manage tillage
   - Add tissues that are slow to degrade

Number #1 recommendation

- To amending a clay soil?

Crop Yield

Low Soil Quality

High Soil Quality

Low

Medium

Input level

High

Input level

Crop Yield

Soil Quality = Yield response?

Compare Soil to Natural Area

To Build SOM

Number #1 recommendation

- To amending a clay soil?
Excess tillage:
erosion, oxidation and decomposition

Targeted tillage

No-till with a killed cover crop

The central contradiction

Sieving soil organic matter

Soil organic matter consists of carbon and nitrogen. Is it possible to simultaneously capture the carbon (to build soil quality) and till to release the nitrogen (to supply plants)?
Soil organic matter ‘sandwich’

Macroaggregate

Foster et al. 1983

Aggregates influence SOM and soil N

- Provide SOM protection
- Higher concentration of C and N than whole soil
- Anaerobic microsites = oxygen excluded
- Limited access by soil organisms

How to build all SOM pools?

Goal: keep mineralizing N while building aggregates and SOM

- Replenish all pools: provide plant and manure residues for active, slow and stable pools. Mixture of OM qualities.
- Manage pool loss: build long-term humus pool in separate zones than short term active pool through zonal tillage. Right time and place tillage.

Soil organic matter pools

Very fast turnover

1 month–few years old

Long-term organic matter

Active organic matter

Microbes

Many years/centuries old

Aggregate building: roots + micros

Lessons from long-term field trials
Living Field Laboratory trial
in SW Michigan, W.K. Kellogg Biological Station, MSU

- Cropping system comparisons since 1993:
  - Continuous Corn vs. Corn-Soybean-Wheat
  - Cover crops: Cereal rye after corn, Red clover frost seeded in wheat
  - Compost: with or without 4 tons/acre (~100 lb/N) of dairy compost applied before corn

LFL Management - SOM in Corn

<table>
<thead>
<tr>
<th>Soil organic matter (%)</th>
<th>No cover</th>
<th>Cover crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>1.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Corn+compost</td>
<td>1.7</td>
<td>2.1</td>
</tr>
<tr>
<td>Rotated Corn</td>
<td>2.2</td>
<td>2.5</td>
</tr>
<tr>
<td>Rotated Corn+Comp</td>
<td>2.3</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Snapp et al., 2010

LFL Compost – Nitrogen Credit

<table>
<thead>
<tr>
<th>Dairy Compost 100 lb N</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>26</td>
<td>55</td>
<td>40</td>
</tr>
<tr>
<td>Historic</td>
<td>18</td>
<td>41</td>
<td>33</td>
</tr>
</tbody>
</table>

Average Current (Year of addition) = 40 lb N/Acre
Average Historic (Past additions) = 30 lb N/Acre

Recommendation: Count on 30 to 40% of N added in compost applied this year
+ 10 to 20% from past years
Potato nitrogen management

Potato systems: slow release nitrogen from mixed residues of compost + rye cover

Diversify cover crop residues

- **Fall**: No-till soybean into wheat residue
- **Spring**: Frost-seed red clover into wheat
- Grow mixed cover crops!

Mixtures of residues - Application of manure with cover crop

Manure Quality Varies

<table>
<thead>
<tr>
<th>Manure type:</th>
<th>Poultry</th>
<th>Swine</th>
<th>Dairy</th>
<th>Beef Cattle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Compost or Aged</td>
<td>Slurry or Lagoon</td>
<td>Depends on feed, bedding, storage</td>
<td>Scrape or pit (pit = similar to swine)</td>
</tr>
<tr>
<td>N content</td>
<td>1-3 % 3-5%</td>
<td>1-3%</td>
<td>1-6%</td>
<td>1-2%</td>
</tr>
<tr>
<td>C content</td>
<td>19-27 %</td>
<td>15-19%</td>
<td>15-18% 40-50% (avail. slow)</td>
<td>16-25% 40-50% (avail. slow)</td>
</tr>
<tr>
<td>pH</td>
<td>Neutral to alkaline</td>
<td>acidic</td>
<td>neutral</td>
<td>Neutral to acidic</td>
</tr>
</tbody>
</table>

Targeted tillage zones

- Separate soil C building zone from N mineralizing zone
Strip tillage zones

Squash in strip-till system

Take home: Diversity and targeting!
- Nitrogen release and carbon build up CAN be managed together
- The goal is mixtures of BROWN (dairy manure, compost, wheat straw and roots, reduced-till) with GREEN (legume hay, poultry or swine manure, green manure, cover crops turned in young)
- Targeted tillage NOT excessive tillage

MSU Extension resources

Advanced Soil Organic Matter Management

Managing Soils

- Developing healthy, productive soils requires an understanding of soil biology, chemistry, and physics. MSU Extension helps farmers and gardeners improve soil health and productivity with practical, research-based information, tools, and resources.

- Soil health is critical to the resilience of our agricultural systems. By promoting healthy soils, we can improve crop yields, reduce input costs, and protect the environment.

- MSU Extension's soil health resources include educational materials, workshops, and webinars. Check them out at extension.msu.edu/Soils.

- For more information, contact the Soil Health Specialist at extension.msu.edu/soilhealth.