Organic Vegetable Gardening

Compost: Part 2

Noontime Talks

Phillippi Farmhouse Market

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OUTLINE

- Overview of topics of noontime talks on organic vegetable gardening
- Introduction to organic vegetable gardening
- Advanced and new techniques of compost making and use
Topics of Noontime Talks for Organic Vegetable Gardening

- Introduction (Nov 23, 2011)
- Edible Flowers (Dec 7, 2011)
- Container Gardening (Dec 21, 2011)
- Worm Composting (Jan 4, 2012)
- Frost Protection (Jan 11, 2012)
- Composting – Part 1 (Jan 25, 2012)
- Transplants (Feb 8, 2012)
Topics of Noontime Talks for Organic Vegetable Gardening

- Composting – Part 2 (Feb 22, 2012)
- Irrigation (March 14, 2012)
- Beneficial Insects (March 28, 2012)
- Companion Planting (April 11, 2012)
- Cover crops (April 22, 2012)
Goals for Noontime Talks on Organic Vegetable Gardening

– Food for your freshest nutrition
– Food for expanding benefits of backyard vegetable gardening
– Food for thought
– Food for your soul
Approach of Noontime Talks on Organic Vegetable Gardening

- Promote the practice of the guidelines in the reference “Vegetable Gardening in Florida” by James M. Stephens. 1999. Univ. of FL, IFAS
- Provide background information on the science and principles from agroecology for successful organic vegetable gardening.
- Provide additional resources available for successful organic vegetable gardening.
Available from UF/IFAS bookstore, see http://ifasbooks.ufl.edu/merchant2/
Also available from your favorite book vender.
Agroecosystem Concept

- An approach that looks at your vegetable garden as a functional whole of interacting living and non living components, i.e. “whole is more than sum of parts”

- A science-based management using models from natural ecosystems

Three processes connect all the parts of the ecosystem:

- Energy Flow is the "power" of the system
- Water Cycling and Nutrient Cycling are the movements of the elements and compounds that plants and animals need to live and grow.
Garden agroecosystems have functional properties & subsystems (e.g., soil organic matter) from biodiversity.
Soil Organic Matter Model

- OM additions start rapid multiplication of bacteria, fungi, and actinomycetes
- As most readily available energy sources are used up, microorganisms again become relatively inactive,
- Leaving behind a dark mixture usually referred to as **humus** - a stable organic compound

Soil Resource Webpage, Univ. of MN, http://www.soils.umn.edu/academics/classes/soil2125/
• Composition
  – all living organisms (microorganisms, earthworms, etc),
  – fresh residues (old plant roots, crop residues, recently added manures),
  – decomposing OM
  – well-decomposed residues (humus).
Humus

✓ a mixture of compounds and complex life chemicals of plant, animal, or microbial origin that are resistant to decomposition and include:

- Humic Acids
- Fulvic Acids
Function of Humus

✓ increases water holding capacity
✓ sticks together & helps establish and maintain a strong crumb structure & aids infiltration
✓ provides some nutrients (N & P) as it is slowly decayed by microbial activity at the rate of 2.5% per year
✓ buffers pH changes
✓ creates good soil “Tilth”
✓ holds nutrients by increasing cation & anion exchange capacity, and chelating capacity
Composting

- Art & science of producing a humus-based, stable organic matter soil amendment by:
  - mixing organic materials properly
  - monitoring resultant biological activity

- Types described today
  - aerobic, thermophilic piles
  - new developments in aerobic type
  - compost tea
  - grub composting
Composting Literature

• Sir Albert Howard, “An Agriculture Testament” (1943)
  – Introduced Indore Compost Making Process
  – Foundation of organic gardening/farming

• J.I Rodale, “Complete Book of Composting” (1960)
  – Father of US organic gardening/farming
Aerobic Composting Basics Review

Cover keeps heat in and prevents water from entering.

Grass cuttings and straw allow air in.

Warm air rises.

Older, bottom parts contain black crumbly compost.

Walls have small gaps keep heat in, they allow air circulation.

Inside the heap, micro-organisms breakdown the organic materials which generates heat.
Aerobic Composting is Alive!

Compost Biota

- Fauna
- Protozoa
- Decomposer microorganisms
  - Bacteria
  - Actinomycetes
  - Fungi
Aerobic, Thermophilic Composting
Review of the Basics

• Organic materials
  – carbon:nitrogen ratio = 30:1
  – less than 2-3 inches particle size
  – moisture (40-60 %)

• Pile building and management
  – layers
  – aeration
  – volume (3’x3’x3-6’)

• Monitoring
  – temperature rise (minimum 131° F for 3 days)

• Management
  – mixing/turning
  – finishing/curing
  – screening
  – maturity tests

Go to http://compostinfo.com/
Provides interactive tool for proper use of raw ingredients
Aerobic Composting Basics

Simplified Temperature Changes in an Aerobic Compost Pile

- A = mesophilic
- B = thermophilic
- C = mesophilic
- D = maturation

Temperature vs. Time

Active Phase

Curing Phase
Aerobic Composting Basics

Importance of turning the pile

- Redistributes microorganisms
- Cools the pile
- Aerates the pile
- Speeds up decomposition
- Allows microbial succession to reoccur
Continued Monitoring...

- After turning, monitor heat cycle again
- Turn when temperature decreases
- Check moisture and add if necessary
- Repeat turnings until temperature ceases to rise (about 4-5 turning cycles)
Phases of Aerobic Composting

- **Mesophilic phase**: moderate temps., lasts for a few days
- **Thermophilic phase**: high temps., lasts from a few days to several weeks
- **Curing and maturation phase**: moderate to ambient temps., lasts 1-2 months.
Succession of microbial communities during composting

- **Mesophilic bacteria** break down soluble, readily degradable compounds (sugars, starches)
- **Thermophilic bacteria** break down proteins, fats, cellulose, hemicellulose
- **Fungi and actinomycetes** (filamentous bacteria) important during curing phase in attacking most resistant compounds
Why cure?

- Assures highest quality product
- pH shifts to neutral
- Soil MO’s re-colonize compost, impart disease suppressing qualities to compost
- If too much C left, use of this compost as a soil amendment may cause a temporary N deficiency, just the opposite of what you want!
- Makes compost optimum for plant growth

Compost Maturity Testing

Homogeneous, Fine-particle Humus-like Material

- This is the final product that you are aiming for at the end of a successful composting process.
Compost Maturity

- **Assure that your compost is mature**
  - Maturity = low microbial activity = fully composted
  - This will avoid ammonia burn in your plants
  - Nitrogen in your garden soil will not be immobilized by unfinished compost and ‘rob’ your plants of nutrients
  - Pathogens (E. coli/Salmonella) are destroyed during a well managed composting process

- **Test your compost!!! And your soil!!!**
  - This will help you determine how much compost your soil needs. More is not always better!
When is my compost done?

- After heating cycles stop
- After curing
- Check for homogenous, fine-particled humus-like appearance
- Earthy smell
- Maturity tests: Solvita test (becoming recognized by highway departments), and others, experience!
  - [www.woodsend.org](http://www.woodsend.org)
Compost Maturity Tests

✓ Sniff test
✓ Bag test
✓ Germination tests
  ✓ with extracts of compost
  ✓ in compost
✓ Plant growth in compost
✓ Solvita test kit
Compost Maturity Testing

The Sniff Test

- Get a sample from the compost pile by hand or in an open container
- Check for foul odors. They indicate anaerobic or airless decomposition is occurring, creating chemicals which can be toxic to plants
- As a rule, foul smelling compost should not be used.
Compost Maturity Testing

The Bag Test

- Used to determine if the compost is ready to be cured or stored for its final stage of stabilization
- Take a small sample of compost from the inside of the pile, wet it thoroughly, and seal the sample in a plastic bag
- Store the closed bag for about a week at room temperature.
- If when you open the bag the compost has a pleasant, earthy odor, rather than a foul odor, it is stable enough to be cured. If not, the composting process should be continued.
Simple Compost Maturity Testing

The Germination Test

- Unfinished compost has phytotoxic compounds (toxic to plants) which inhibit seed germination, especially with highly sensitive cress and bean seeds.

- Test cress seed germination in a starting flat with a shallow layer of compost and planting a predetermined number of seeds. (germination in 2-3 days)

- Test bean germination in several 4 inch pots with compost, planting 3 to 4 seeds in each pot (germination in 5-7 days)
Simple Compost Maturity Testing

The Germination Test (cont.)

- At the same time, count out the same number of seeds and germinate these in damp paper towels.

- Compare both the germination speed and the number of seeds that germinate in towels with the number that germinate in compost treatment.

- If the plants are not healthy, the compost is not mature and needs to continue composting or curing, the final stage of stabilizing compost.

http://sarasota.ifas.ufl.edu/compost-info/tutorial/compost-maturity-test.shtml
Solvita Test for Compost Maturity

- Test based on monitoring both CO\textsubscript{2} respiration & NH\textsubscript{3} volatilization
- High rates of emissions indicate actively degrading compost
- Tests results together give a compost maturity index

http://solvita.com/compost-information
Compost Byproducts

The Composting Process

- Water
- Heat
- $\text{CO}_2; \text{NH}_3$

Raw Materials

- Organic Matter
- Minerals
- Water
- Micro-organisms

Compost Pile

Finished compost

- Organic matter, minerals, water, microbes

$\text{O}_2$
Table 1 Compost Maturity Index Calculator

use the Ammonium and CO2 paddle color numbers and read across and down to where the columns meet

<table>
<thead>
<tr>
<th>SOLVITA Ammonia Test Result is:</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLow / No NH₃</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Low NH₃</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Medium NH₃</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>High NH3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Very High NH₃</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Example: If the NH₃ result is 2, and the CO₂ result is 6, then the Maturity Index is: 4
Table 2: Status of Composting Process

<table>
<thead>
<tr>
<th>Solvita Ammonia #</th>
<th>Fresh Mix</th>
<th>Active</th>
<th>Ideal Curing</th>
<th>Mature</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>possible high C:N or too acidic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Example: If the NH₃ result is 2, and the CO₂ result is 6, then the process is Active moving into Curing.
Lignin and Biodegradability

- Higher % lignin in feedstock, lower the bioavailability to microbes
- Forage labs can measure lignin content
- Can estimate bioavailability of organic material if you know the % lignin and % volatile solids
- Equation:
  \[ 0.83 - (0.028 \times \text{lignin}\% / \text{volatile solids}\% ) \]
  (Source: Cornell Composting website-research under anaerobic conditions!!).
What Is Lignin?

Lignin is a complex chemical compound most commonly derived from wood, and an integral part of the secondary cell walls of plants. Its most commonly noted function is the support through strengthening of wood (xylem cells) in trees.
Humus Comparison

- a mixture of compounds and complex life chemicals of plant, animal, or microbial origin that are resistant to decomposition and include:

Humic Acids

Fulvic Acids

Humic Acids
## Correction Table for %C and C:N Ratio based on % Lignin

<table>
<thead>
<tr>
<th>Material</th>
<th>% C (total)</th>
<th>C:N (total)</th>
<th>% lignin</th>
<th>%C biodegradable</th>
<th>C:N biodegradable</th>
<th>% Cell wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>newsprint</td>
<td>39</td>
<td>115</td>
<td>21</td>
<td>18</td>
<td>54</td>
<td>97</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>51</td>
<td>89</td>
<td>23</td>
<td>34</td>
<td>58</td>
<td>95</td>
</tr>
<tr>
<td>Poultry manure</td>
<td>43</td>
<td>9.6</td>
<td>2</td>
<td>42</td>
<td>9.3</td>
<td>38</td>
</tr>
<tr>
<td>Maple wood chip</td>
<td>50</td>
<td>51</td>
<td>13</td>
<td>44</td>
<td>45</td>
<td>32</td>
</tr>
</tbody>
</table>

Source: Cornell Composting Webpage
Composting Lignin Factor

Lignin decomposition under aerobic conditions

- Lignin decomposition much higher under aerobic than anaerobic conditions
- Promote conditions for white rot fungi
  - Add small quantities of N to woody materials (as little as 0.12% N)
  - Promote high moisture conditions (65-83%)
  - High temperatures (thermophilic range)
Historical Perspectives

It has been recognized for centuries that composts can support natural disease control.

However, composts differ widely in this ability. Furthermore, some batches kill plants; others inhibit or stimulate plant growth!

Result: Growers shied away from using composts in their operations until recently!
Substitution of peat with composted bark began in 1954. Natural suppression of root rots was observed immediately!
This Phytophthora root rot bioassay proved that natural suppression in compost mixes is effective

Spring et al., 1980, Phytopathol. 70:1209-1212
Composting Bark Factor

Pythium Root Rot of Poinsettia

H4 Peat

H2-3 Peat

Pine Bark + H4 Peat

Note severe root rot in dark peat mix in top row
## Composting Bark Factor

### Media Naturally Suppressive to Pythium and Phytophthora Root Rots

<table>
<thead>
<tr>
<th>Media</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aged Pine Bark</td>
<td>60 - 65%</td>
</tr>
<tr>
<td>Fibrous Sphagnum Peat</td>
<td>15%</td>
</tr>
<tr>
<td>Composted Biosolids</td>
<td>8 - 12%</td>
</tr>
<tr>
<td>Silica Sand/Expanded Shale</td>
<td>5 - 10%</td>
</tr>
</tbody>
</table>
Composting Bark Factor

Why does composted OM suppress disease?

• Composted OM supports growth of microorganisms but competition prevails
• Therefore, antibiotics and parasitism enzymes are produced
• Composted OM is friable, supports drainage but also water retention
• Result: natural disease control
Why are diseases increased by fresh organic matter?

- Fresh OM releases organic nutrients and supports pathogen growth
- Free nutrients suppress antibiotics and enzymes required for parasitism
- Fresh OM binds water and maintains soil under the mulch wet late into spring
- Result: Stimulation of root rots, no control
Composting Bark Factor

How long do compost treatments last?

- It depends on the type of material from which the compost is prepared:
  - Bark: 2-3 yrs
  - Manures: 1-2 yrs
  - Food wastes: 2-6 months

- Lignin and protected cellulose are the key substrates that determine longevity
Factors Affecting Suppression of Plant Diseases with Composts

- Heat kill (Pathogens, Beneficial microorganisms, Weed Seeds, etc.)

- Organic Matter Decomposition Level (stability)
  - Fresh Materials - negative
  - Composted - positive
  - Pyrolyzed - negative

- Recolonization by microbes after peak heating

- Chemical and physical factors
Composting Bark Factor

**Compost Microflora**

- Pathogens and most beneficial microorganisms are killed by natural heating during composting. Thus, biocontrol agents must colonize composts after peak heating to induce specific suppression.

- Composts produced adjacent to forests have broad spectrum disease suppressive effects. However, composting sites are far from natural environments.

- Thus, 98% of all composts are deficient in natural disease suppression.
Advanced Composting: BIOCHAR

The Composting Process

- Water
- Heat
- CO₂; NH₃

Organic Matter
Minerals
Water
Micro-organisms

Raw Materials

Compost Pile

Finished compost

Organic matter, minerals, water, microbes

O₂
Advanced Composting: Biochar

Experiment: BIOCHAR Bulking Agent in Composting

http://www.biorefinery.uga.edu/carbon%20cycl%20apps%20main.html
What Is Biochar?
Biochar Soil Amendment History

“Terra Preta” Soil in Amazonia

Ferralsol

Terra Preta

B. Glaser
Example 1: Chernozem or mollisol

- Most agriculturally productive soils (Duchaufour, 1998)
- Residues from vegetation fires, such as black carbon (BC) (Glaser et al., 2000)
- BC constituting up to 45% of the SOM
- BC is several millennia in age (Schmidt et al., 2002)
Biochar Properties & History

Carbonized Organic Matter resistance

⇒ Charcoal is a long-term carbon sink

JOHANNES LEHMANN, JOHN GAUNT, and MARCO RONDON  Mitigation and Adaptation Strategies for Global Change 2006
Biochar Composting

Compost with and without biochar

0% biochar

20% biochar

20% biochar

http://www.biorefinery.uga.edu/carbon%20cycl%20apps%20main.html
Biochar Composting Effects

Faster decomposition at higher temperatures.

![Graph showing temperature vs. weeks for different composting conditions.](http://www.biorefinery.uga.edu/carbon%20cycl%20apps%20main.html)
Biochar Composting Effects

Reduced Nitrogen Losses with 20% biochar

- Ammonia emissions reduced by up to 64%
- Total N losses reduced by up to 52%

Graph showing NH₃ ppmv over days with different biochar concentrations.
The major soil amendment benefits of biochar:
- The extremely high affinity of nutrients to biochar (adsorption) & increased soil fertility
- The extremely high persistence of biochar (stability)

Additional beneficial effects of biochar include:
- Increased soil microbial functions
- Increased soil water availability
Garden Scale Biochar Production and Composting

See the video:
http://www.youtube.com/watch?v=RXMUmby8PpU&feature=related
Compost Extract and Tea

What are they?

- The liquid portion of compost soaked ("steeped") in water

Extract =
- Non-aerated
  - 1 part compost, 3-10 parts water
  - Occasional stirring
  - 1-3 weeks

Tea =
- Aerated
  - 1 part compost, 10-50 parts water
  - Air injection or constant circulation for 6-24 hours
  - Often made with additives (molasses, yeast extract, algal powder, kelp) to increase microbial biomass

http://organic.kysu.edu/CompostTea.pdf
Gardening Applications

Compost tea uses

- Foliar fertilizer
- Disease suppression
  - Foliar
  - Soil-borne
- Residue decomposition
- Enhanced soil biology
- Pest suppression

Steve Wright, Pennsylvania vineyard. Rodale Institute Photo.
Does foliar feeding work?

- Foliar fertilization... works sometimes, not always
  - Gives quick shot of micronutrients, taken up rapidly by plant
    - Radioactively labeled micronutrients applied as foliar fertilizer can be found in plant roots 60 minutes later
  - Very helpful for certain deficiencies
    - Ca deficiency in fruit
    - Zn deficiency
    - Nutrients unavailable due to acid soils
  - Works best when stomata are open (morning and evening, cool, moist conditions)
  - Mist works better than drench
  - Short-term solution; not a substitute for long-term soil building
Can compost tea suppress disease?

• Yes!
  – Litterick et al. (2004) lists 24 unique crop/pathogen combinations in which disease has been suppressed by compost tea*
    • Tomato early blight, late blight, powdery mildew & bacterial spot
    • Grape leaf blight, grey mould, downy mildew & powdery mildew
    • Strawberry grey mould & redcore

• … and no.
  – Control is unpredictable and sometimes insufficient

Compost Tea Research

Not all compost is created equal

- Most biocontrol agents killed during composting
  - NOP requires C:N between 25:1 and 40:1 and temperature between 131 and 170°F for 15 days. Sufficient to reduce human pathogen levels below detectable limits.

- Biocontrol agents must recolonize during curing process
  - Composts produced near forests have higher biocontrol agent concentration
  - Recolonization takes up to a month after temperatures fall

Not all compost is created equal

- Treatments with single biocontrol agents have little effect; diversity is better
- Create a compost microenvironment that favors many beneficial organisms
  - 40-50% water content
  - pH > 5.0
  - Low salinity (bark mulch compost has less salt than manure-based compost)
  - Low C:N (excessive N promotes many diseases)
  - Presence of decomposition-resistant material (lignins and cellulose) that supports beneficial microbes

Compost tea and food safety: The next spinach scare?

- No recorded cases of food-borne illness from compost tea treatment
  - “Absence of evidence is not evidence of absence.”
    - Carl Sagan
  - “The producer must manage plant and animal materials to maintain or improve soil organic matter content in a manner that does not contribute to contamination of crops, soil, or water by plant nutrients, pathogenic organisms, heavy metals, or residues of prohibited substances.”
    - NOP standards
  - “Pending further NOP policy development, [compost tea] must meet restrictions for use of raw manure.”
    - OMRI Generic Materials List, June 2004
NOP Compost Tea Task Force Recommendations

- Compost extract: Compost held in potable water for < 1 hr
- Compost tea: Compost held in water for > 1 hr
  - Aerated
    - 1 part compost, 10-50 parts water
    - Air injection or constant circulation for 12-24 hours
    - Often used additives (molasses, yeast extract, algal powder) to increase microbial biomass
  - Non-aerated
    - 1 part compost, 3-10 parts water
    - Occasional stirring
    - 1-3 weeks

Additives increase microbial biomass (both good and bad)
Compost Tea Safety

NOP Compost Tea Task Force Recommendations (April, 2004)

• Use drinkable water
• Sanitize equipment before use
• Use NOP-compliant compost (both plant and manure-based composts)
• No restriction:
  – Compost tea without additives
  – Compost extract (steeped for < 1 hr)
  – Compost tea with additives IF production system (compost + additives + equipment) makes tea that meets EPA water quality guidelines for E. coli and enterococci in two pre-tests
• 90/120 day pre-harvest restriction:
  – Untested compost tea with additives
  – Soil applications of raw manure extract/tea or compost leachate
• Prohibited:
  – Foliar applications of raw manure extract/tea or compost leachate
  – Use of compost teas for edible sprout production
Grub Composting

• The specific bioconversion process by which valuable proteins and fats of kitchen wastes are captured and recycled, rather than degraded, into usable biomass by a beneficial decomposer is referred to as Grub Composting.

• The signature species utilized in such systems is the juvenile Black Soldier Fly, *Hermetia illucens*

http://thebiopod.com/
Grub Composting

Bio Pod Example

- grub larvae composter & grower
- Use grub larvae as food high in fats & protein to fish, herp & chickens

See the video: http://thebiopod.com/

Black Soldier Fly

Grub larvae

Adult
Walt Whitman, “Behold This Compost” (1855)

A celebratory poem in his seminal book ‘Leaves of Grass’

“Something startles me where I thought I was safest, I withdraw from the still woods I loved . . .

How can you be alive you growths of spring? How can you furnish health you blood of herbs, roots, orchards, grain?

Are they not continually putting distemper'd corpses within you? Is not every continent work'd over and over with sour dead? Where have you disposed of their carcasses? . . .

Behold this compost! behold it well!

Perhaps every mite has once form'd part of a sick person--yet behold! The grass of spring covers the prairies, The bean bursts noiselessly through the mould in the garden, The delicate spear of the onion pierces upward, . . .

What chemistry! . . .”

Summary

• Organic vegetable gardening fundamentally depends on developing a functional soil ecosystem

• Practices are designed to enhance soil quality and health

• “Feed the soil so that the soil can feed the plant”
Online Resources

- Bomford, M. Compost Tea. KYSU
  http://organic.kysu.edu/CompostTea.pdf
- Copperbrand, L. The Biology of Composting. UW.
  http://www.wastenot-organics.wisc.edu/05composting/presentations/biologyofcompostpile.pdf
- Cornell Composting. Compost Trouble Shooting
  http://compost.css.cornell.edu/trouble.html
- Elliot, A. Backyard Composting: Avoid Toxic Compost
- Hoitink, H. Dept of Plant Pathology, OSU
  http://plantpath.osu.edu/people-and-programs/faculty-directory/emeritus/hoitink-harry-a-j/index_html
Online Resources

- Steiner, C. 2009. Waste Biomass & Prospects of Biochar. UGA.
  http://www.biorefinery.uga.edu/docs/Steiner%20FPPC2009%2009_10_09.pdf

- Stromberger, M. Composting Organisms, CSU
  http://www.extsoilcrop.colostate.edu/Soils/powerpoint/compost/Composting Organisms.pdf