Opportunities and Challenges in Composting Organic Waste

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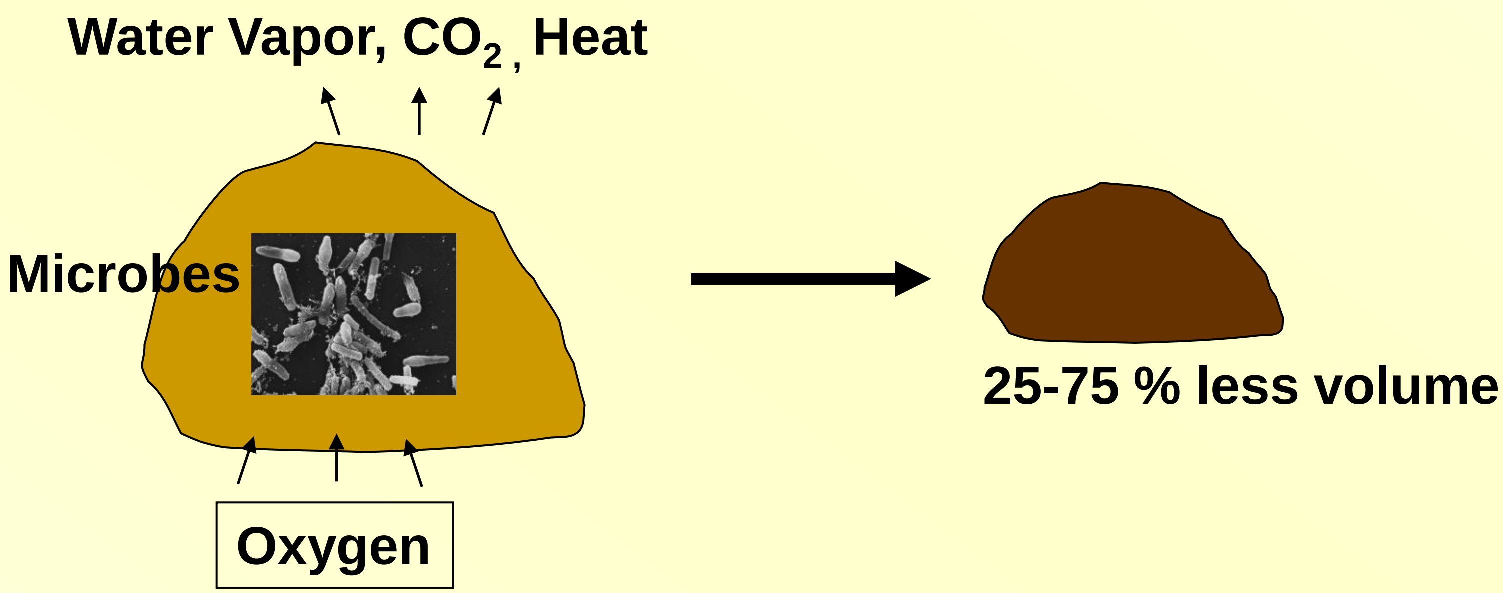
Composting Process

Fresh Organic Material **Stabilized Organic Residue**




Manures, Mortality
Municipal Solid Waste
BioSolids

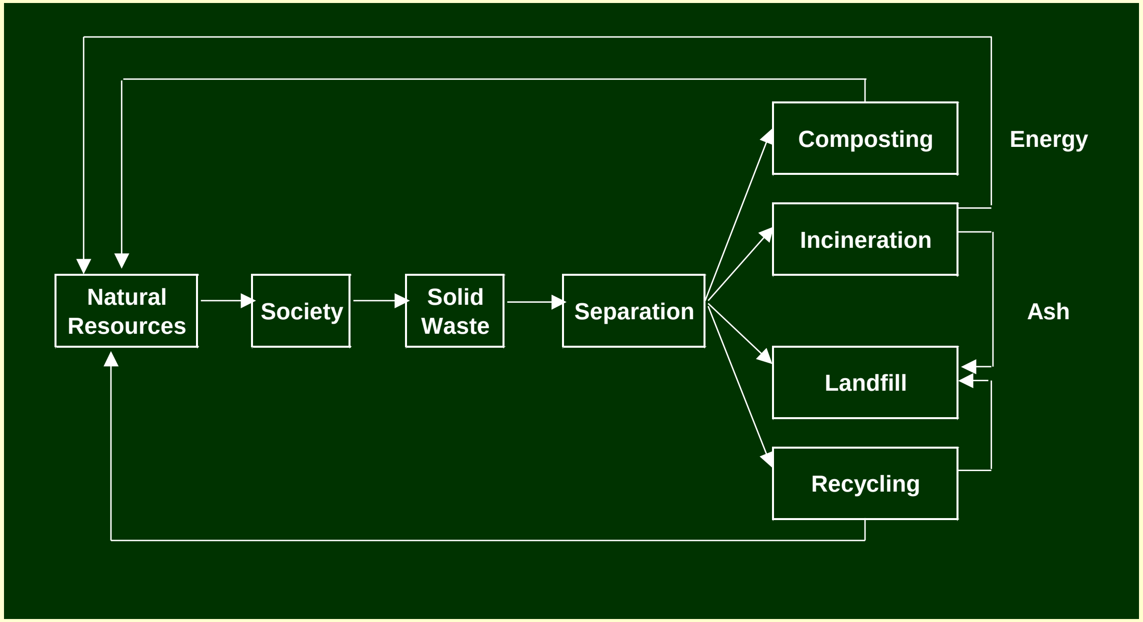
Composting In USA*

• MSW	15	facilities
• BioSolids	250	
• Food Waste	138	
• Yard Trimmings	3316	
• Farm Waste/Mortalities	>5000	

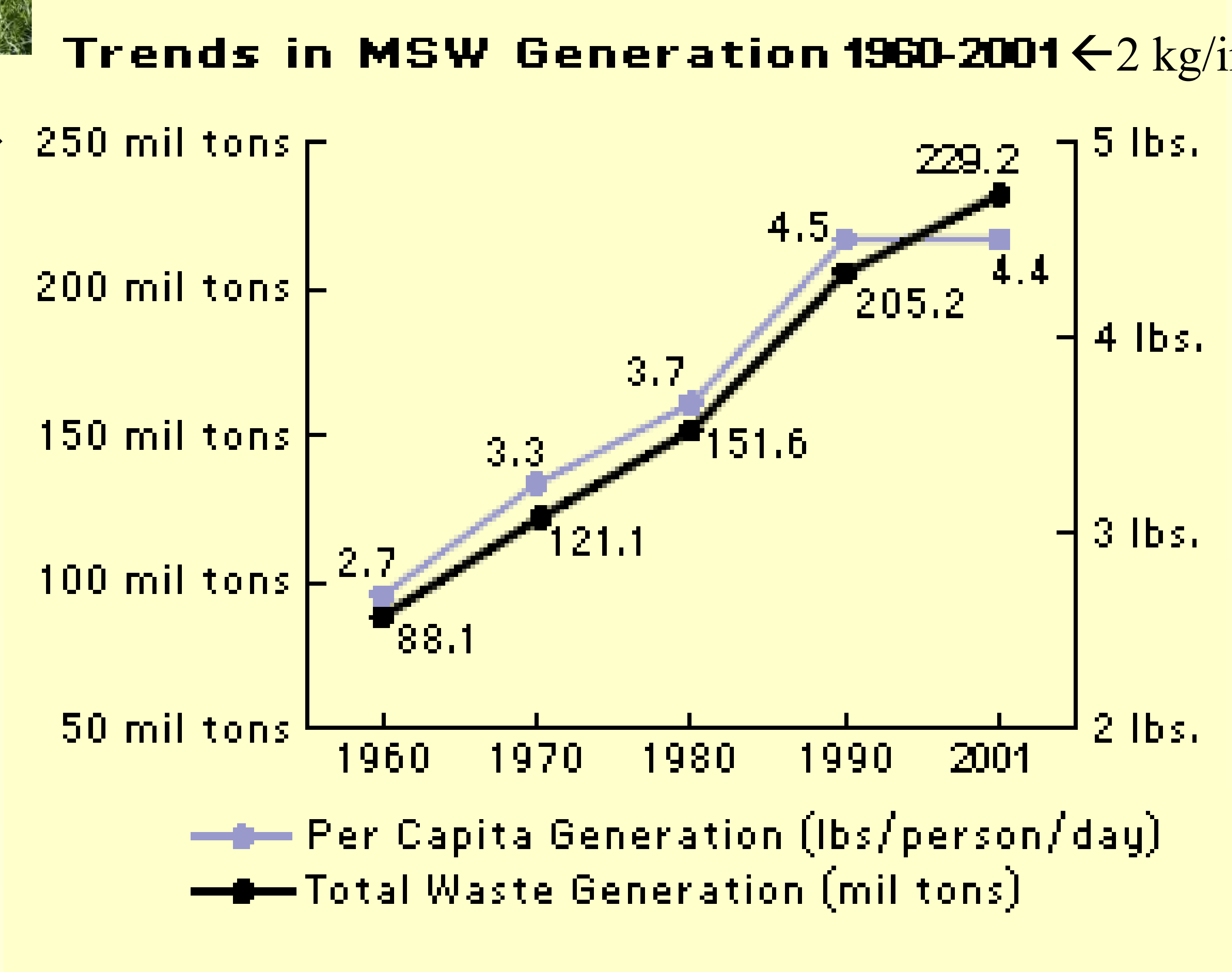
* Data for 1997

USA EPA Solid Waste Hierarchy

1) Source Reduction (including reuse)
2) Recycling
3) Composting
4) Combustion
5) Landfills



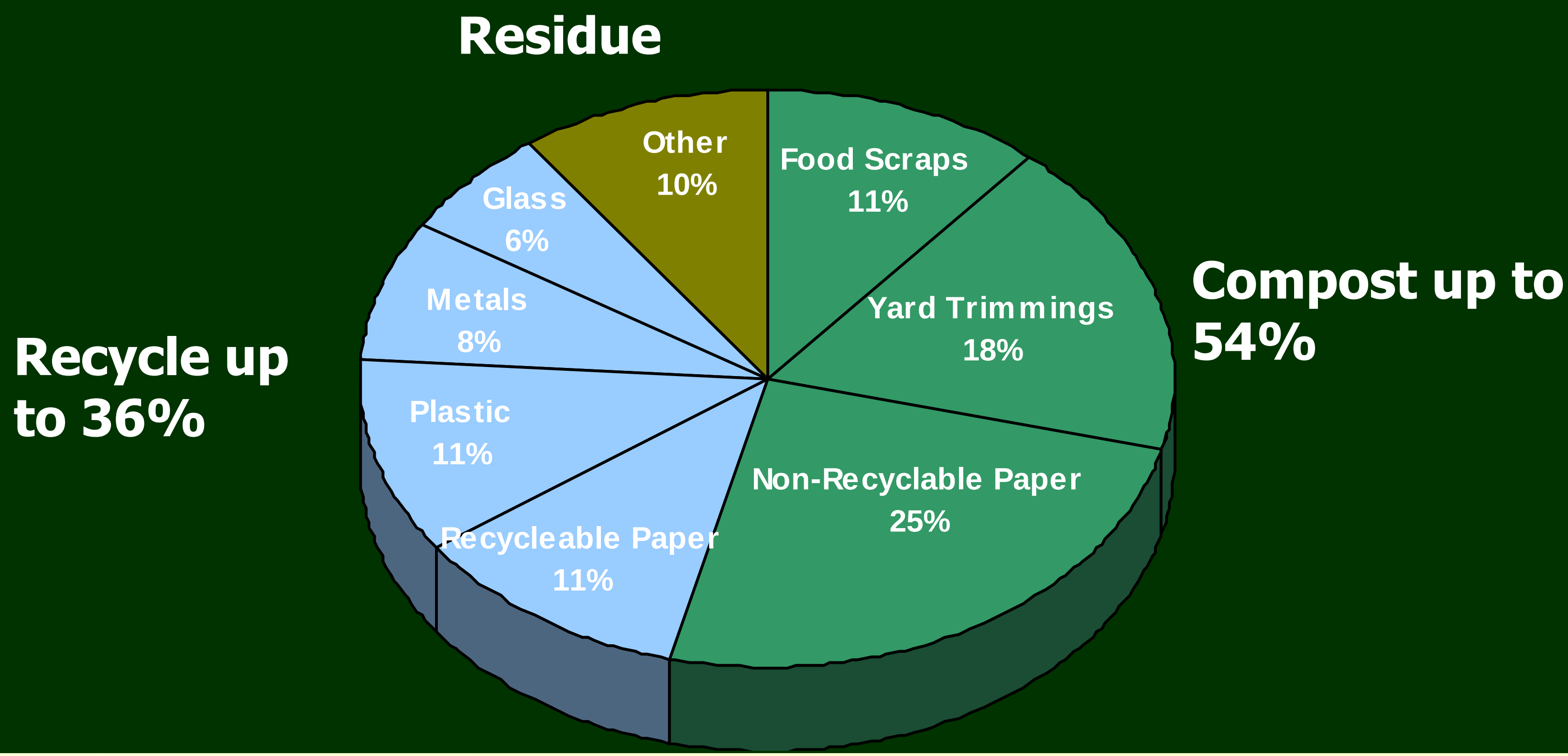
U.S. Population
287.8 Million



←2 kg/inh/day

227t →

U.S. Municipal Solid Waste 208,000,000 t/yr



Currently MSW in U.S.: 23% recycled, 7 % composted, 15% burned, 55% land filled

Landfill 55% MSW

- ~3500 Landfills in USA.
- Tipping fees as low as $16-20/t. Average for U.S. is $35/t.
- Bans on placing yard trimmings in landfills has lead to more composting.

Composting Mixed MSW – sites have been decreasing.

- Ohio limits uses (landfill cover currently).
- Issues of plastics, sharps, ...
- Value of mixed MSW compost only $1-3/t.
- Reason for composting – reduce volume, minimize gas and leachate problems at landfills.

Composting of Yard Trimmings

- Over 3200 sites in U.S.
- Unknown how many mulch operations
- Compost value $20-60/t

Norcal Composting Collects Food Scraps from Restaurants, Hotels, Markets, Homes

Education of people was critical to show the value of source separating,

Norcal recycling efforts make a big difference

April 19, 2002

WITH Earth Day just around the corner, we were pleased to hear of Norcal Waste Systems Inc.'s venture into Oakland's recycling efforts.

In less than two years, Norcal has recruited 55 city business to take about 300 tons of food remnants a month and turn them into compost that can be sold to organic farmers.

It may sound like a small step, but as environmentalists will always point out, every small recycling step helps in the stewardship of planet Earth.

On Site Food Waste Composting

- Composting cost per ton high.

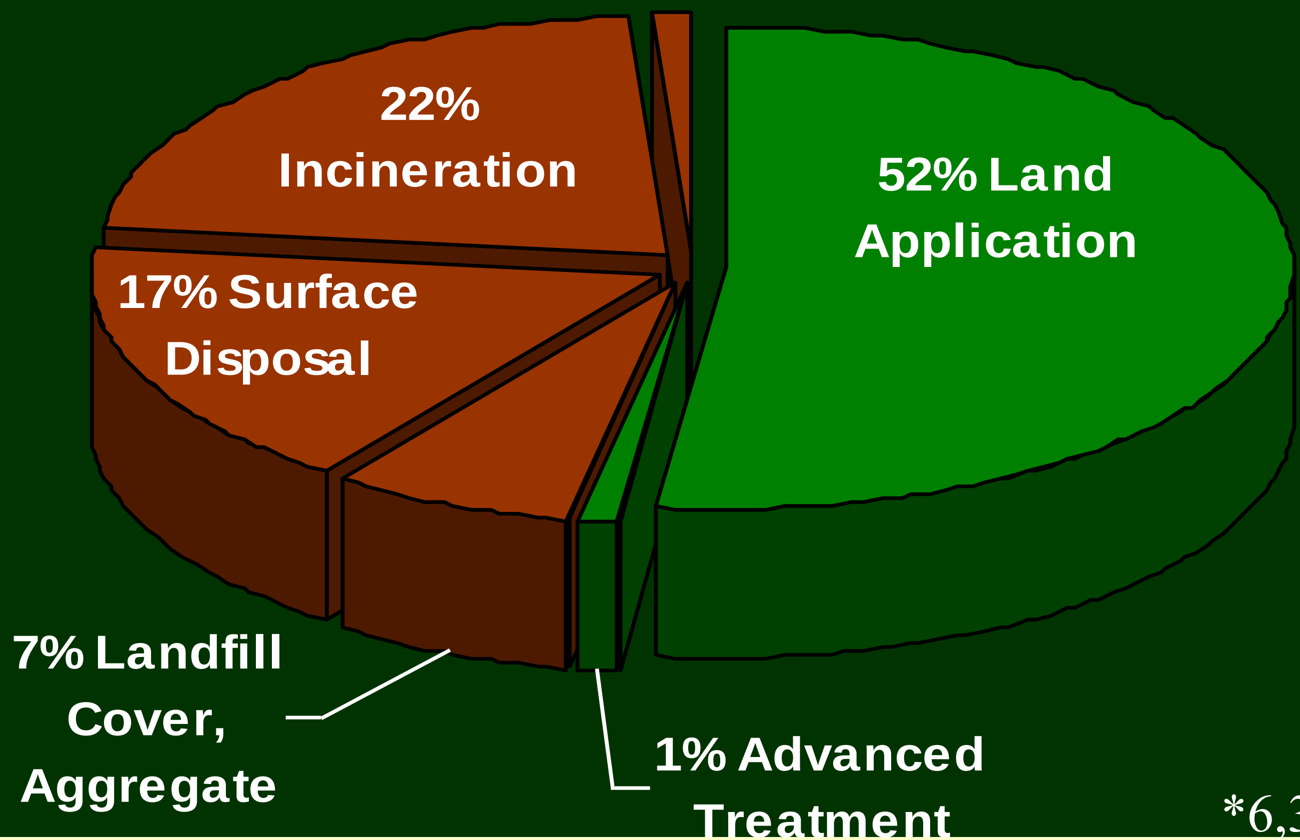
Earth Tub

Green Mountain System

MSW Issues in USA

- Competing with landfills which charge only \$16-20/t (Need for more landfill restrictions?)
- Source separated waste desired for producing high quality compost. Examples: yard trimmings, foodwaste.
- Bio degradable packaging and eating utensils can lower cost of collecting/composting food waste.
- Food Waste – Economics of on site versus off site

Biosolids Use and Disposal
126,000,000 t/yr *



*6,300,000 dt/yr

Biosolids

Direct Land Application

Composting in Vessel

Composting in Aerated or Static Windrow

Biosolids Issues in USA

- Land application lowest cost: $82/dry t
  (however, concerns over pathogens, water quality)
- Composting: $173/ dry t (based on cake 22% ds)
- New separation technology: 30% solids
  - reduces amendment 38%, reduces cost ???
- Need to lower composting cost. More efficient operations. Static pile versus in-vessel.

U.S. Livestock and Poultry Manure Production*

	Million Head	Manure t/yr
	Livestock	
Market Hogs	**60.4**	**29,200,000**
Beef Cows	**33.4**	**509,800,000**
Market Cattle	**14.9**	**133,500,000**
Milk Cows	**9.1**	**212,100,000**
	Poultry	
Caged Layers	**334**	**14,400,000**
Broilers	**8500**	**31,300,000**
Turkeys	**283**	**8,500,000**
Totals		**938,800,000**

*Based on USDA statistics and estimated daily production per animal listed. Total amount far in excess of 1 billion t. Amount of manure collected and land applied or composted unknown.

Agricultural Waste Issues in USA

- Land application has lowest cost (however, concerns over pathogens, air, water quality.
- Transportation of liquid manures beyond 10 km can exceed value of nutrients in manure.
- Some new housing/manure management systems lend themselves to composting manure.
- Need to lower composting cost.
- Need to find value added markets for compost.

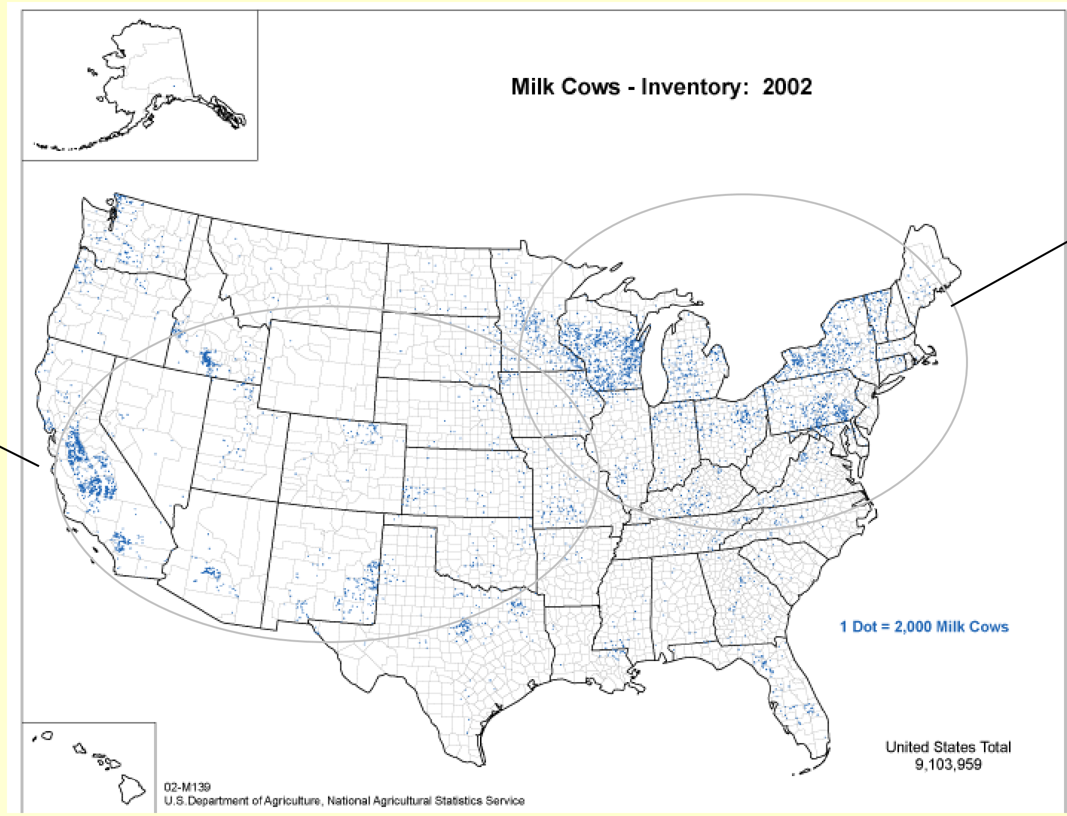
Location in U.S. Affects Approaches to Composting Manures

<u>South West U.S.</u>

Dry Climate

No amendment needed

Very Large Operations



<u>Midwest and North East U.S.</u>

Wet Climate

Need to add amendment?

Most < 700 cows

Need to use cover over compost in winter.

Regulations in the U.S.

- Process to further reduce pathogens (PFRP) - know as US EPA 503 regulations. Enacted for biosolids.

  ≥ 55 C for 3 days in-vessel

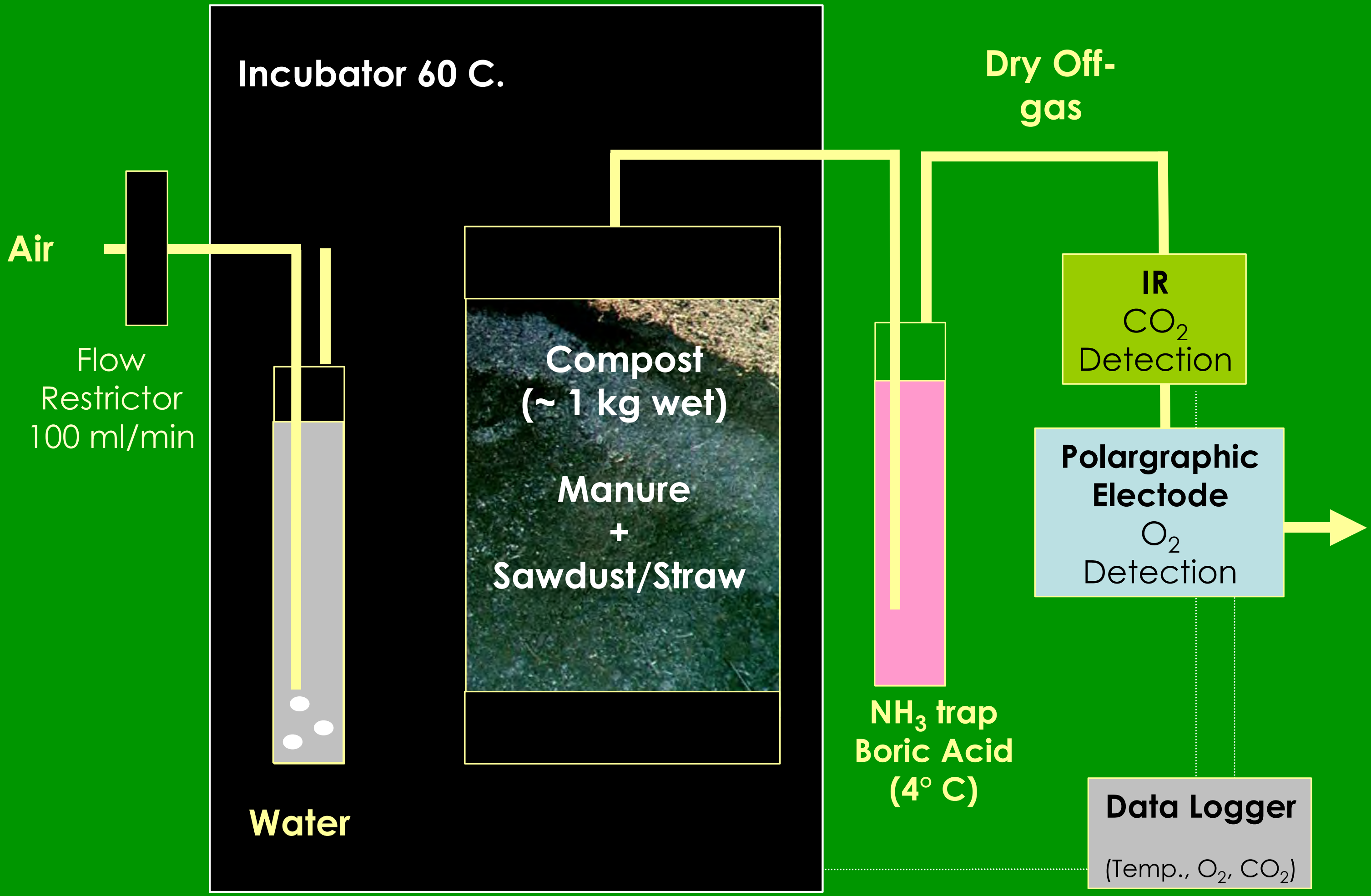
  ≥ 55 C , 5 turns, 15 days for windrow

- 2003/2004 studies at OARDC/OSU looked at survival of pathogens in manure during liquid storage or composting.
  - *E.coli* survival (rough type), *E.coli* survival (smooth type), *Salmonella, Listeria* , Cryptosporidium, *Mycobacterium paratuberculosis*

Simulated manure lagoon treatment

Bioreactor vessels for compost and pack simulation

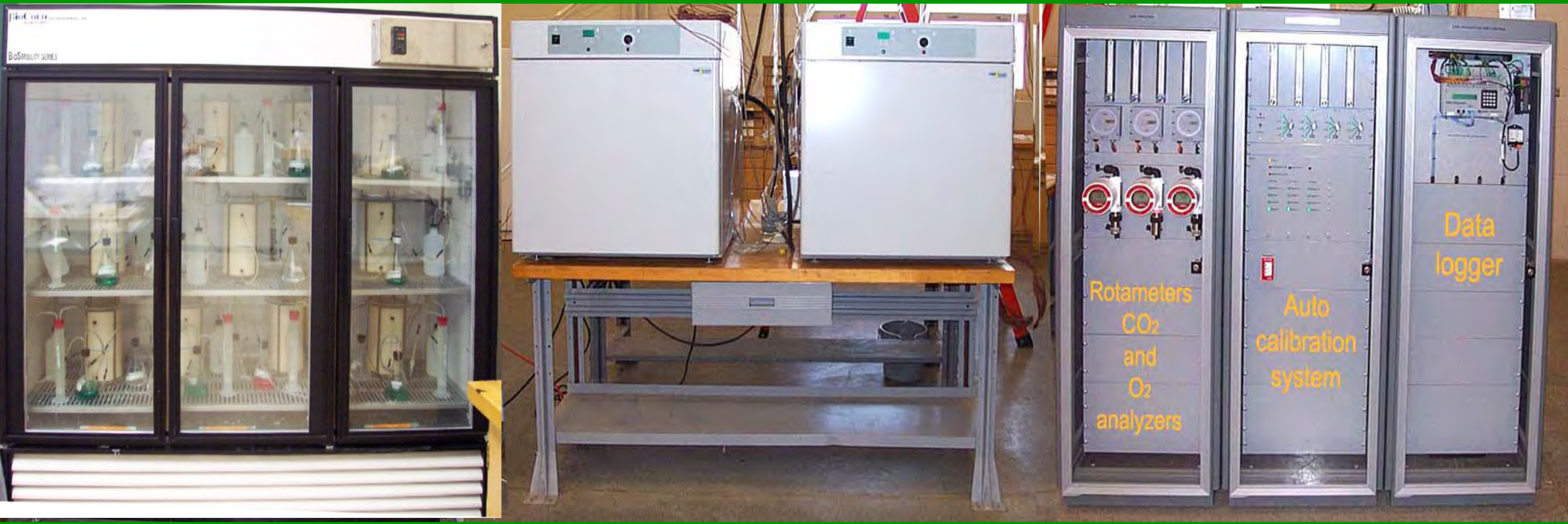
Compost Reactor System

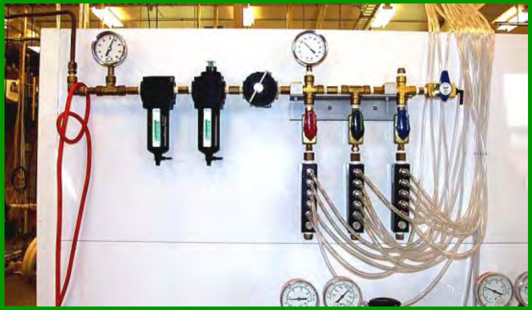


Bioreactor System

Bioreactor incubators

CO_2, O_2 and temperature measurement, calibration and data acquisition.



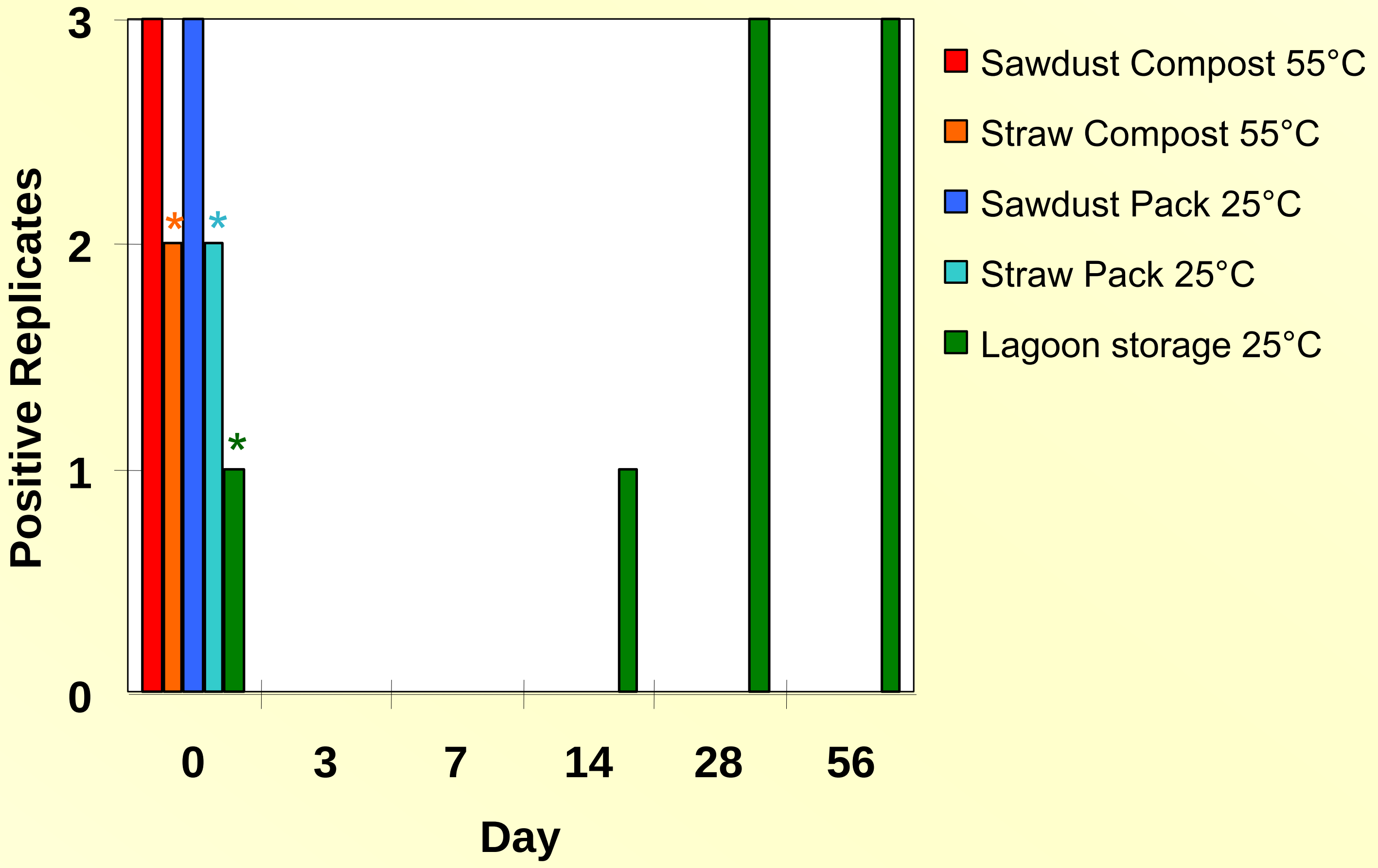


Flow restrictor system (air 100 ±3 ml/min)

Water condenser and ammonia trap (4° C.)

Data collection computer

Mycobacterium paratuberculosis



For detailed information contact michel.36@osu.edu

Controlling Odor, Complying with Clean Air and Water Act

- Use biofilters, acid scrubbers on compost operations control odor, emissions.
- Manage feedstock C/N to reduce ammonia loss.
- Managing airflow to control ammonia.
- Manage runoff from compost site.
- Developing new livestock facilities:
  - Manure Belt/Composting Systems for poultry
  - High Rise Hog Facility

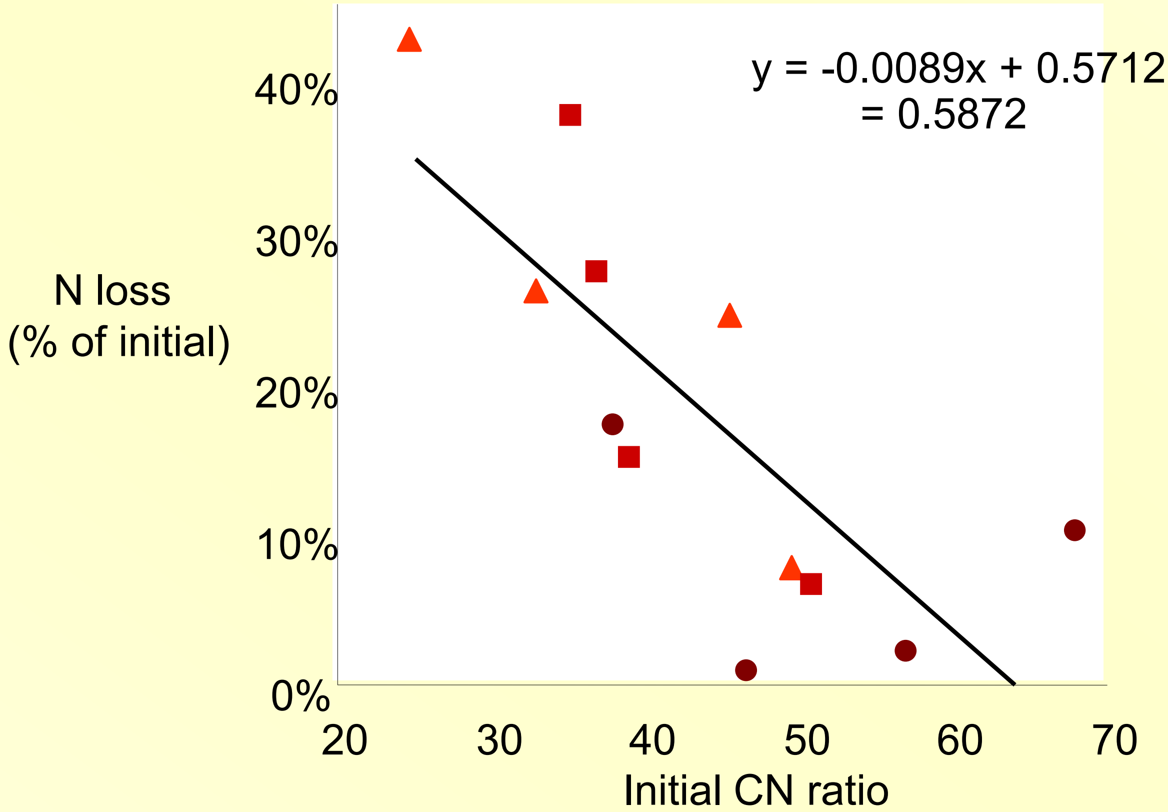
Using a Biofilter to Manage Odors

New Milford Farms, Inc./Nestlé USA, Inc.

50,000 t/y of raw materials :

- Yard, agricultural, and food wastes
- Biofilter on exhaust air

Increasing C/N Reduces NH_3 Losses



N-Losses during composting dairy manure
(% lost of initial amount)

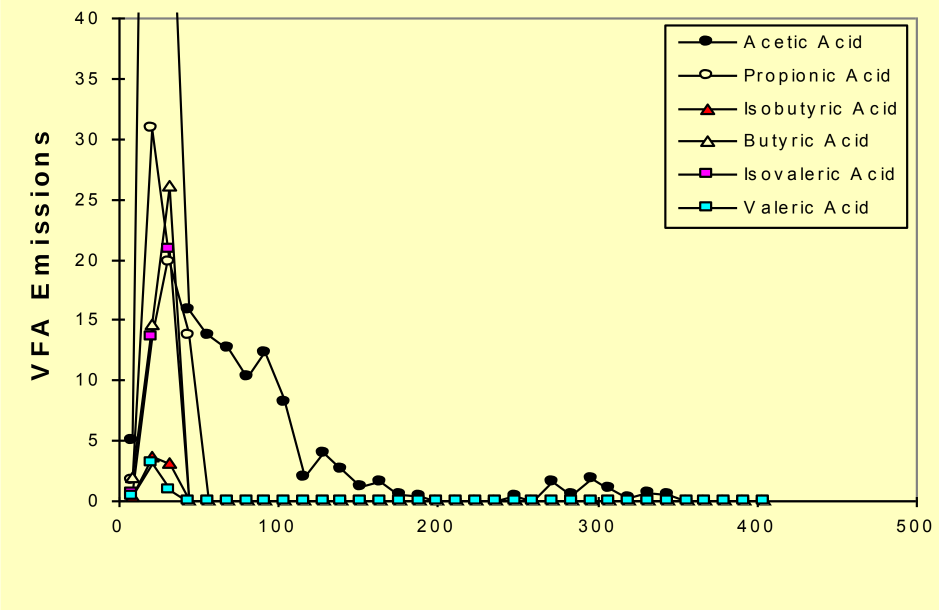
Michel et al., 2004

Aerobic, Low Airflow Destroys Volatile Acids, Reduces Odor

Acids Evaluated:	Acetic	Propionic	Isobutyric
	Butyric	Isovaleric	Valeric

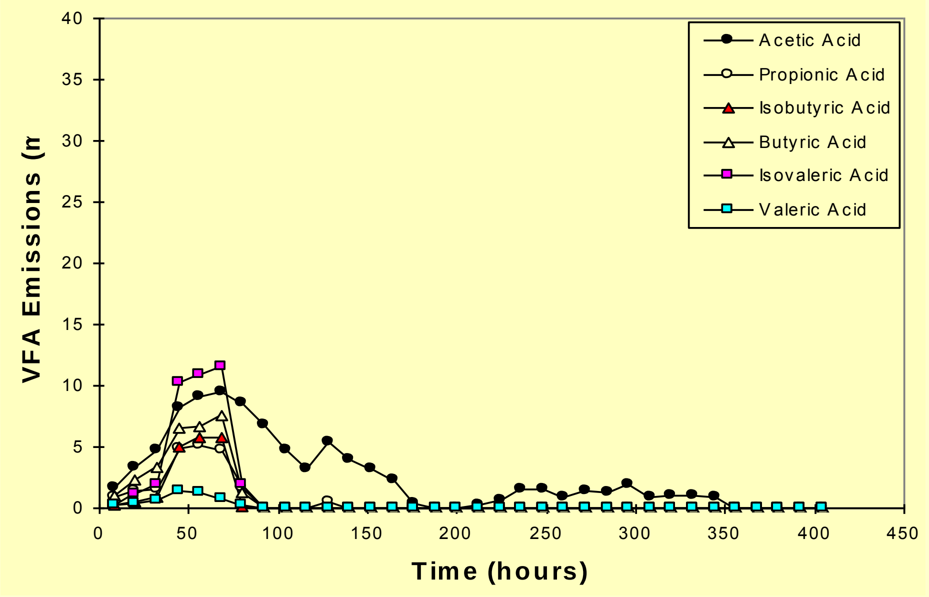
VFAs – cont.aer. – Run 173-99 (swine)

Continuous Aeration Run 173-99
Swine/Sawdust Mixture



VFAs – int. aer. – Run 173-99 (swine)

Intermittent Aeration Run 173-99
Swine/Sawdust Mixture

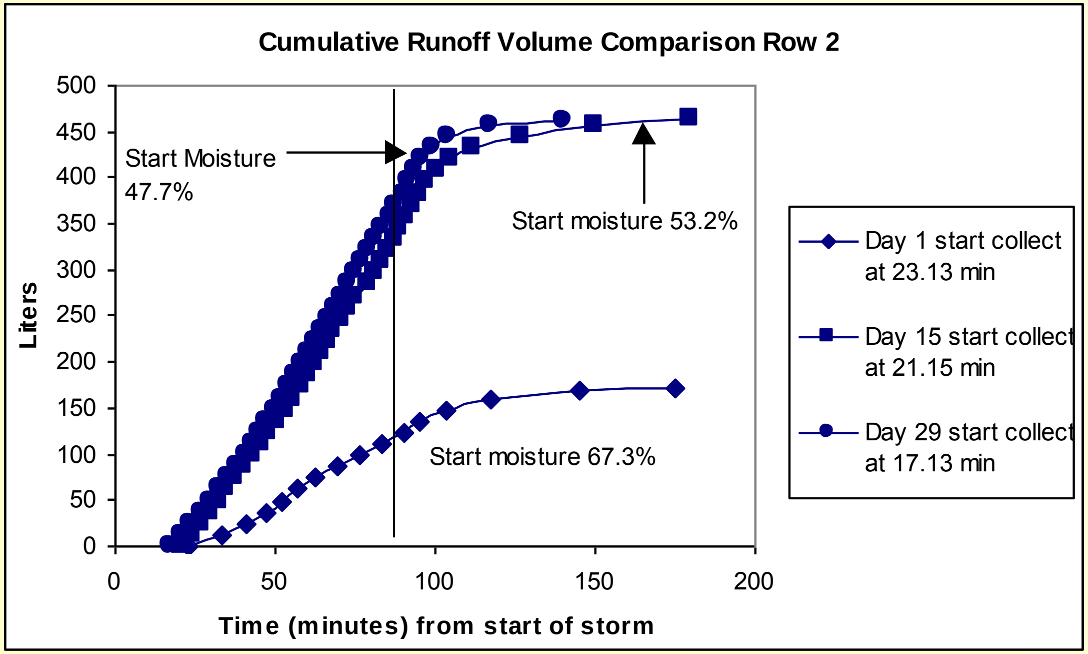


Wiles et al., 2004

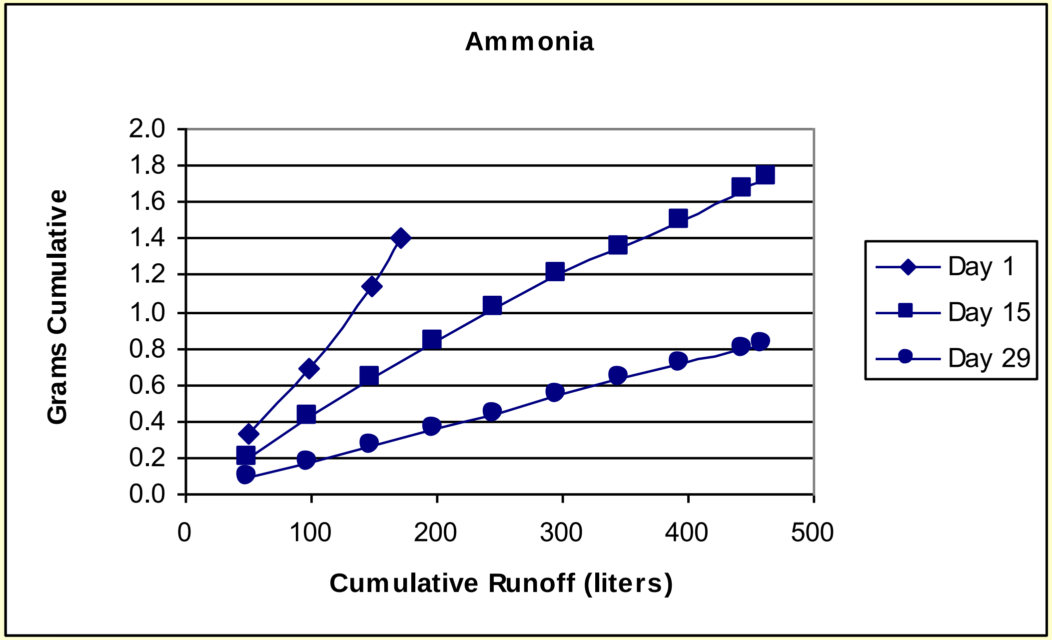
Rainfall Runoff From Compost Windrows

- Pad size – 20,000 sq. ft. concrete, 1-2 % slope
- Woodchip filter, lower end
- 3 cell wetland to treat runoff 25 year storm

Rainfall Simulator



Collection of Runoff



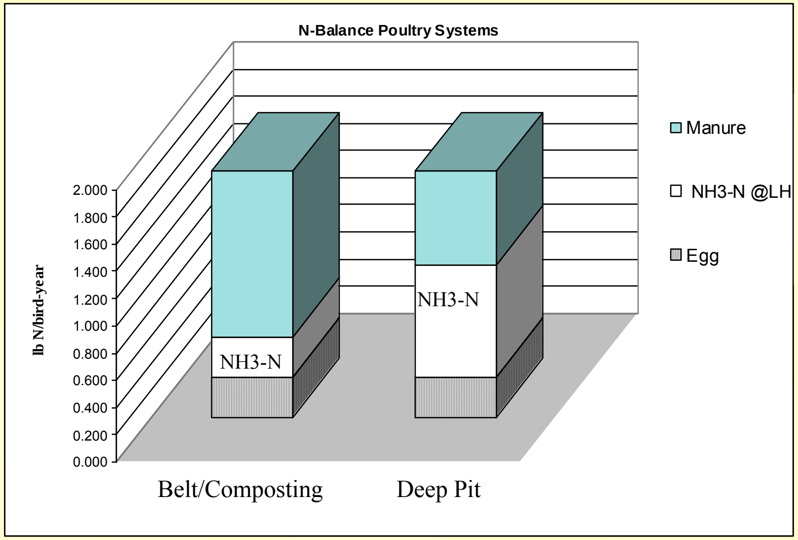
Manure Belt System with Composting for Poultry

One million birds use system at DayLay Farms. Manure dries on belt from 70% to 50-55% moisture. Manure goes to compost building.

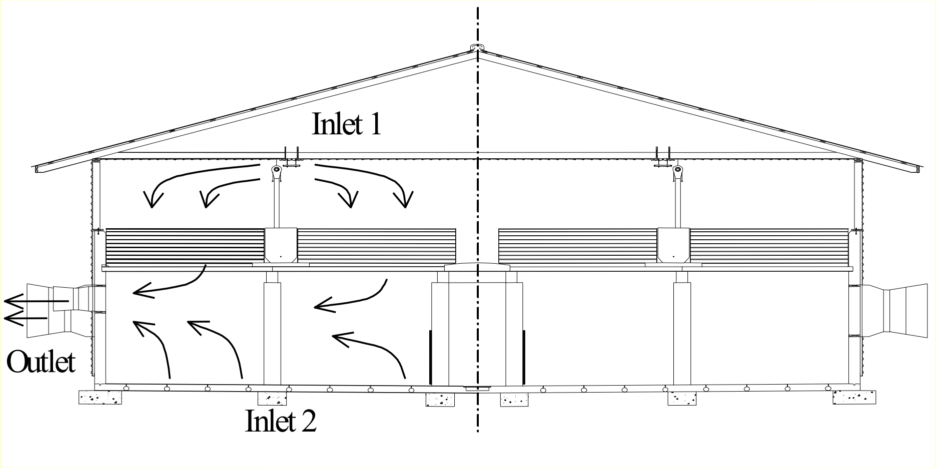
Compost building and turning machines at DayLay Farms. Two buildings have 12 lanes and one has 6 lanes with one turning machine per 6 lanes.

Composted material has 10-20% moisture, granular nature

NH3 losses cut in half compared to conventional deep pit.



High-Rise^{TM} Hog Building



Manure moved out of building. Moisture of manure/drying bed material was 65% wb.

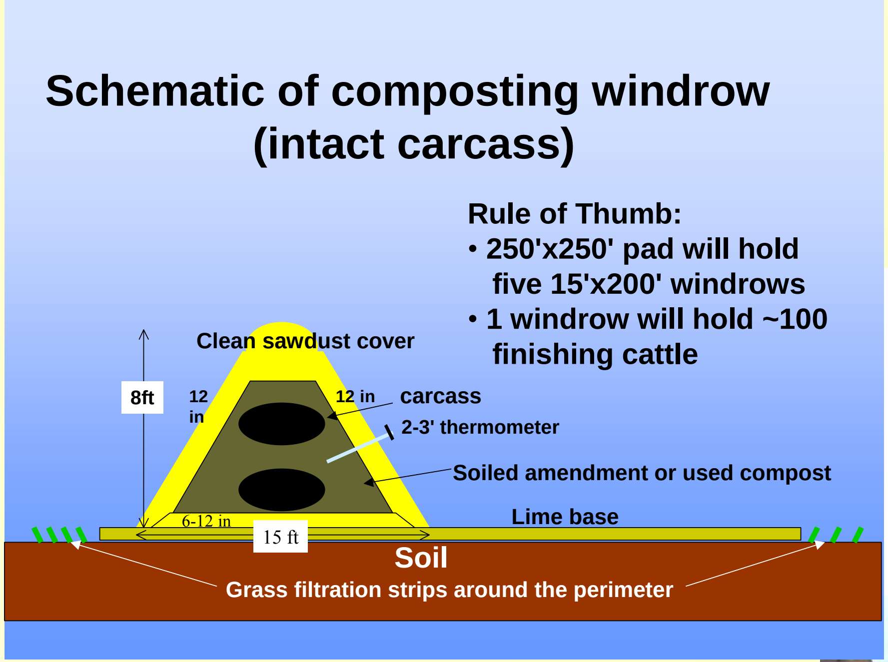
Material being windrow composted.

Static Pile Composting of Yard Trimmings

(PTI, Seattle, Washington)

Static Pile Composting of Yard Trimmings
(Price Barnes, Delaware, Ohio)

Static Pile Composting of Dead Animals as an Alternative to Rendering



Turned Windrow Composting of Dairy Manure & Sawdust.

(Sigrist Farms, Ohio)

Using a skid loader to turn manure. The farm has a turning machine but seldom uses it.

Sigrist Farms, Ohio

Compost is stored under roof for curing, approximately 6 months. Material is then bagged for marketing.

Sigrist Farms finds screening is essential for marketing a quality product. Market as a bagged product (about 18 kg per bag) as Bull Country Compost.

Turned Windrow Composting of Cattle Manure and Yard Trimmings
(Dan Young Farm, Ohio)

Dan Young speaking to a group of farmers, agricultural specialists, university persons at August field day.

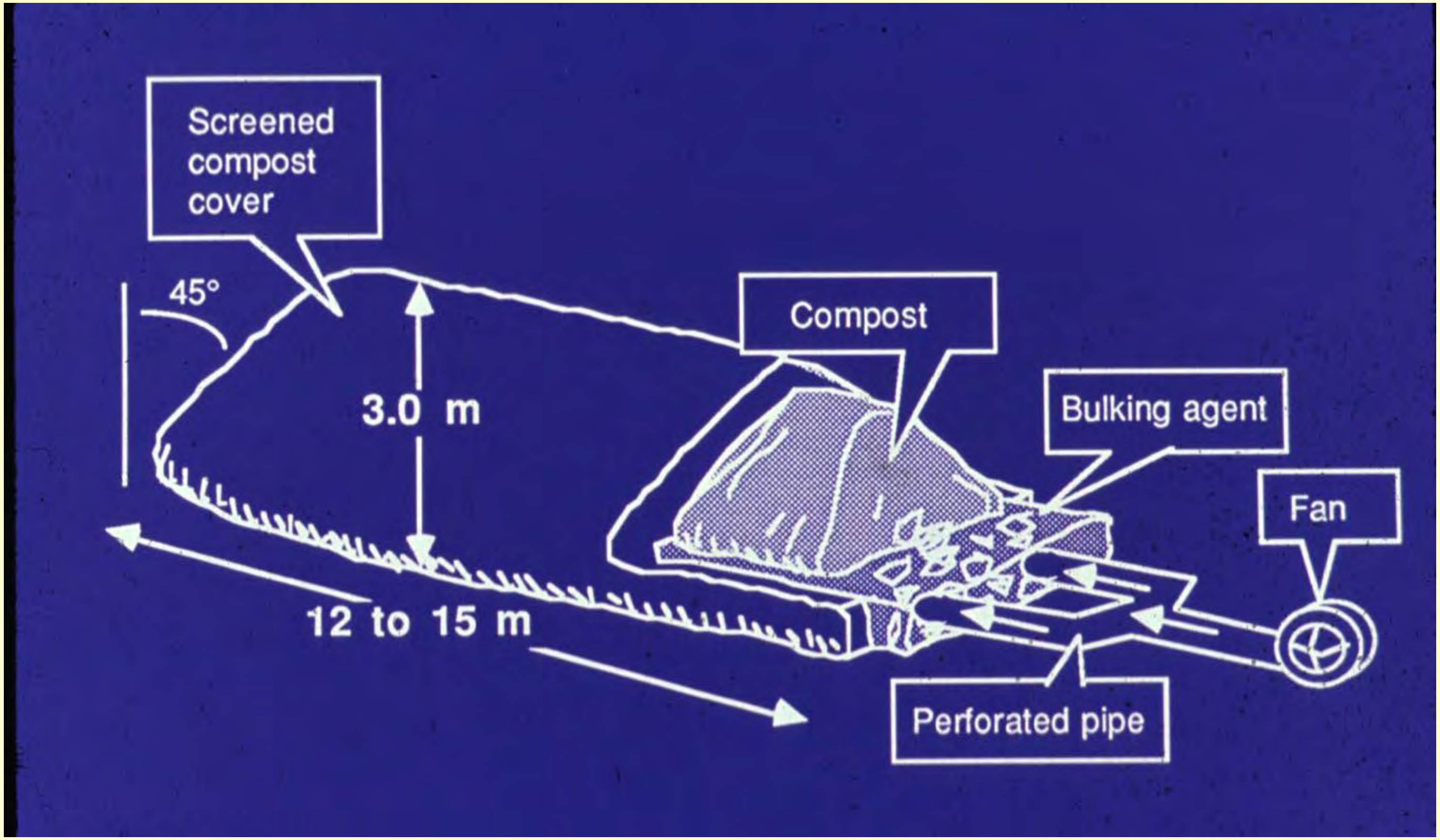
Compost turner and water are added to tank. Water addition is often necessary early in the process if starting with materials less than 60% moisture.

Dan Young Farm, Ohio.

Fleece cover is used to shed rainfall from finished compost (important in wet climate) since finished compost has little activity to evaporate moisture. Cover will last over 5 years.

Product is marketed in mini bulk bags as well as truckloads. Suburban customers enjoy mini bulk bags are delivered with no mess in the driveway. Bags have a refundable deposit.

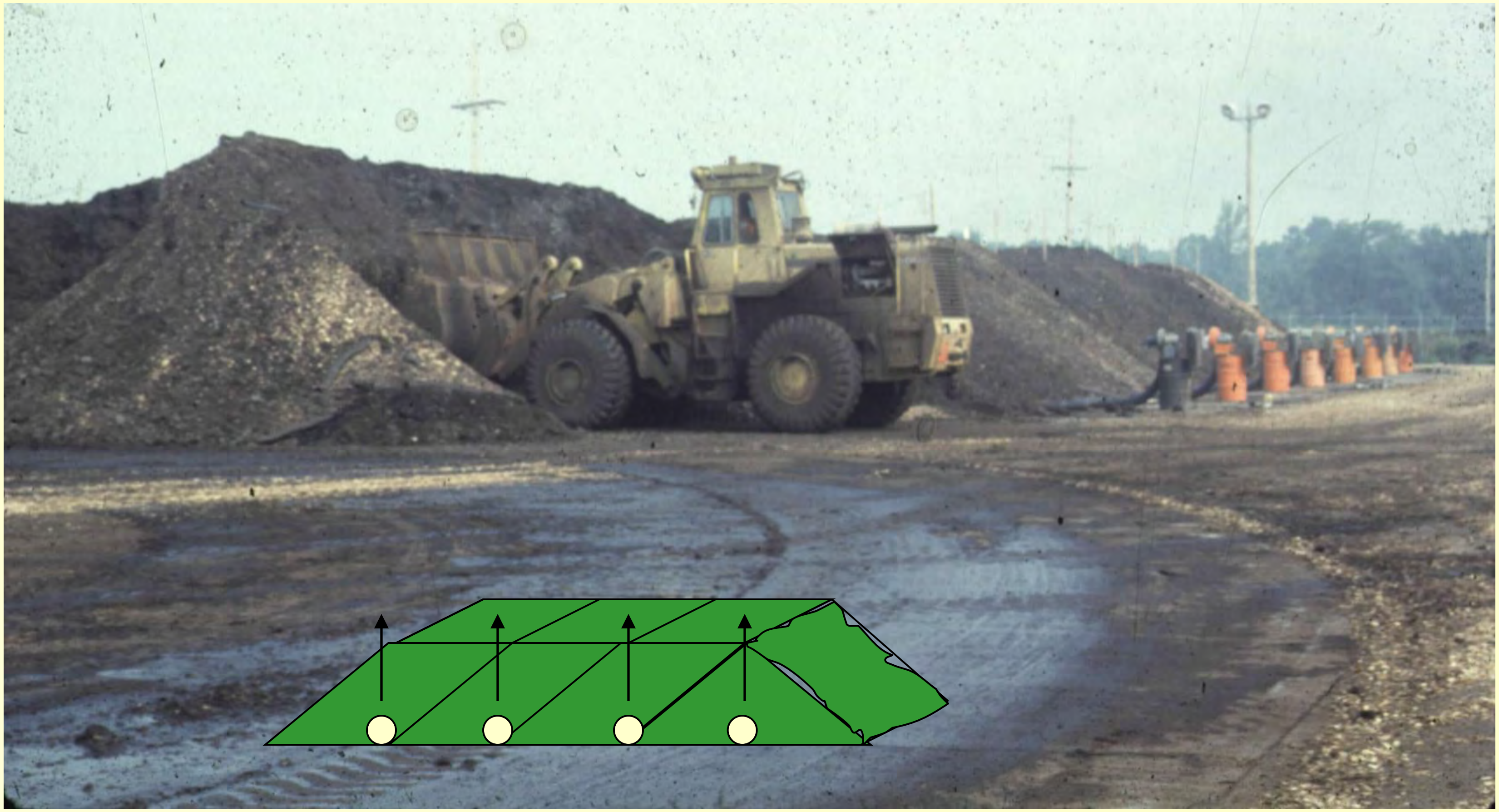
Forced Aerated Windrow



Perforated pipes distribute air in compost. Hole spacing is a function of length, pipe diameter and depth of compost. Maximum length is 22-30 m. Air can be pushed or pulled through the pile.

Aerated Static Pile for Composting Biosolids and Woodchips.

(Columbus, Ohio, 1994)



Wedge-shaped approach with air pushed through the pile.

Aerated Static Pile for Composting Biosolids and Woodchips
(Columbus, Ohio, 2004)

Wedge shaped approach with air pulled through the pile then pushed through a biofilter.

Aerated static pile for composting biosolids/ woodchips in "Ag Bag" did not prove effective in Ohio's high humidity climate.

"Ag Bag" used for yard and food waste in California. Operators claim it is effective in a dryer climate.

Aerated Turned Windrows.
(DayLay Farms, Ohio)

Unamended poultry manure is composted in the first 45 m of the windrow and turned 18 times during the 54-day process.

In-Vessel Forced Aeration System
(Paygro, Ohio)

Composting of cattle manure and food and yard wastes is completed in 21-28 days.

In-Vessel Composting
(Akron, Ohio)

Biosolids, sawdust, woodchips and yard waste are composted in an aerated system with turning in 21-28 days.

Controllable Factors

Compost Mix

- Amendments (type)
- Percent Recycled
- Inoculation
- Nutrient Balance, C/N
- Initial Moisture
- Initial Ash (fct. Materials)
- Porosity, Bulk Density
- Particle Size
- Chemical pH

Operations

- Compost Temperature, Oxygen
- Aeration Schedule
- Percent Recycle Air
- Inlet air T & RH
- Stirring Frequency
- Moisture Control
- Retention time
- Curing time
- Pile Shape, Depth, Volume

Guidelines for Composting

- C/N: {25:1 - 40:1}
- Moisture: {45-65 %}
- Particle Size: {0.8 – 1.2 cm}
- Porosity: {35-60%}
- Bulk Density: {< 640 kg/m^3}
- Temperature {45 – 68 C}
- Oxygen {> 5%}
- pH self adjusting {6.5 – 8.5}

Calculating C/N Ratio

- Base on biodegradable C and N

- C:N = $\dfrac{\text{Wt. biodegradable carbon}}{\text{Wt. (Organic N + NH4-N + NO3-N)}}$

Mixing Dairy Cattle Manure

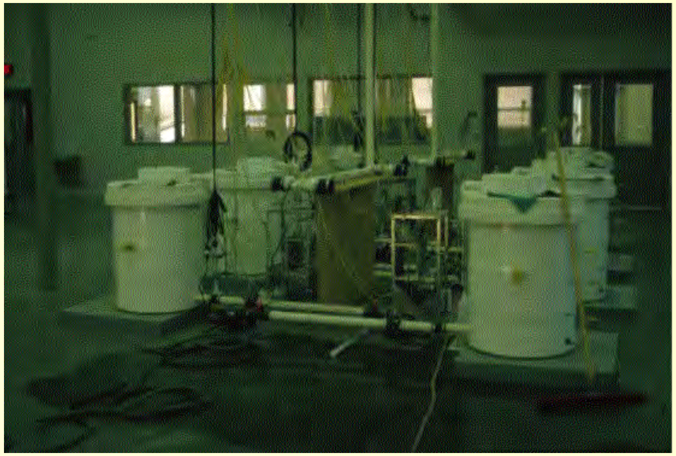
ITEM MATERIAL	Vol Ratio dec	Mass Ratio dec	Moist wb %	C db %	N db %	C/N db
dairy (free stall)	1.00	1.00	81.2	44.6	2.64	16.9
sawdust	1.17	0.33	16.0	49.8	0.16	311.0
recycle site compost	0.00	0.00	44.6	43.5	1.50	29.0
water	0.00	0.00	1.0	0.0	0.00	0.00
Initial Mix			64.9	47.7	1.16	41.2

For excel spreadsheet go to
www.oardc.ohio-state.edu/ocamm/COEC.htm

Laboratory at OSU/OARDC Used in Controlled Pilot Scale Studies on Process Kinetics

Compost Research Building at OSU/OARDC, Wooster, Ohio

Mission Control Center at composting building



Eight 200 L aerated reactor vessels with temperature control and variable set point.

Dry Matter Loss

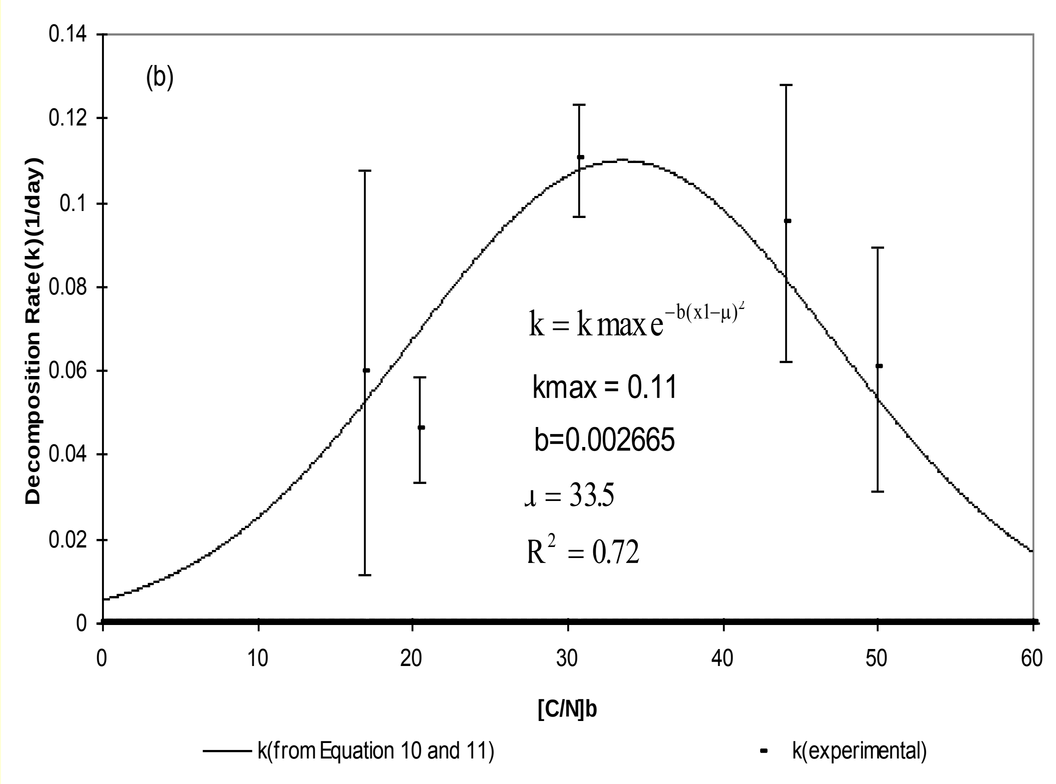
• Stir 1 time/week	15.5% dm loss
• Stir 3 times/week	18.1% dm loss

• No water added	17.6% dm loss
• Add water	36.1% dm loss

C/N Effect on Nitrogen Loss
(amended caged layer manure)

C/N ratio	DM_{loss}	N_{loss}
15	14.8%	43.7%
20	15.3%	30.6%
25	18.3%	26.6%

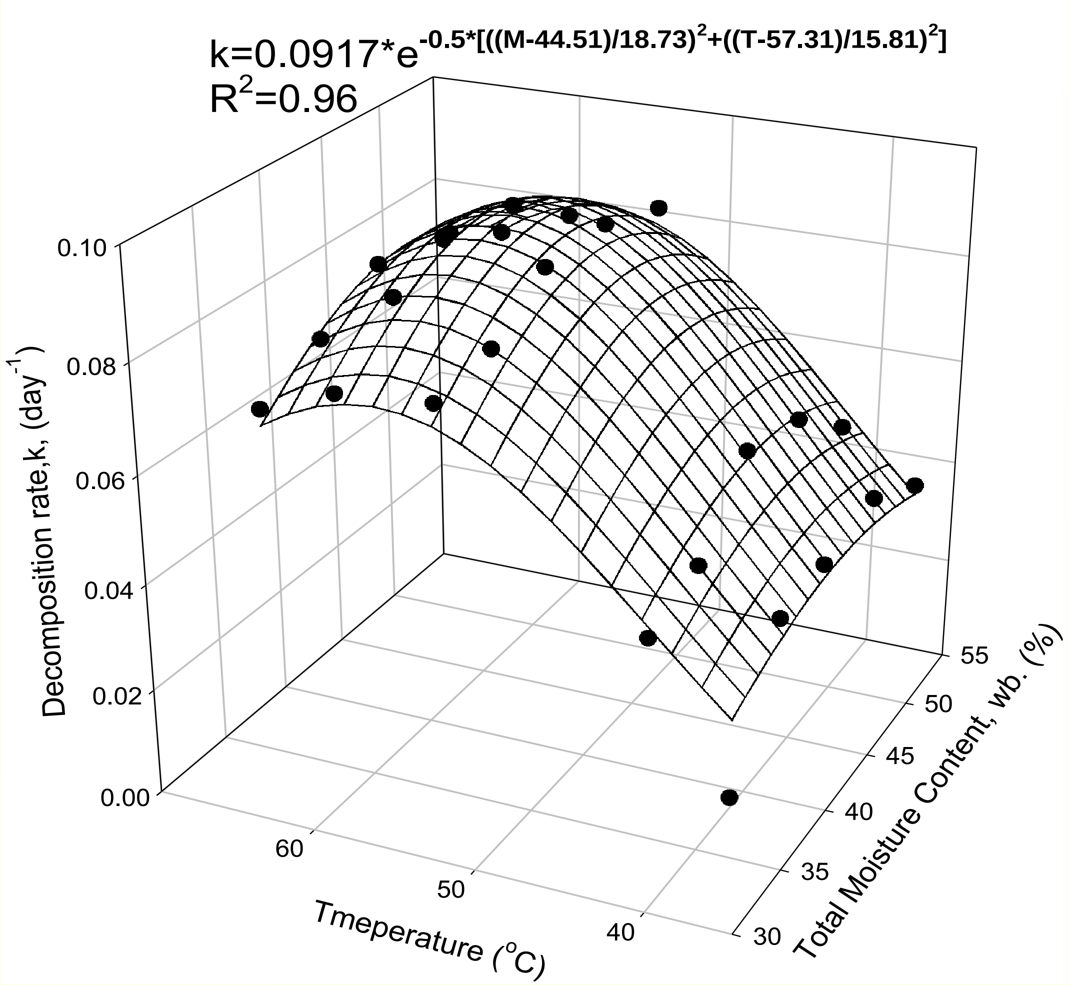
C/N Effect on Decomposition Rate



Study on mixture of paper mill sludge (PS) and broiler litter (BL).
Optimum C/N was approximately 35.
Compost temperature = 60 ^{0}C.

Effect of Moisture and Operating Temperature on Decomposition Rates

Study on mixture of paper mill sludge (PS) and broiler litter (BL) with C/N = 32. Gaussian function used to describe relationship.



Ekinci, OARDC, 2001

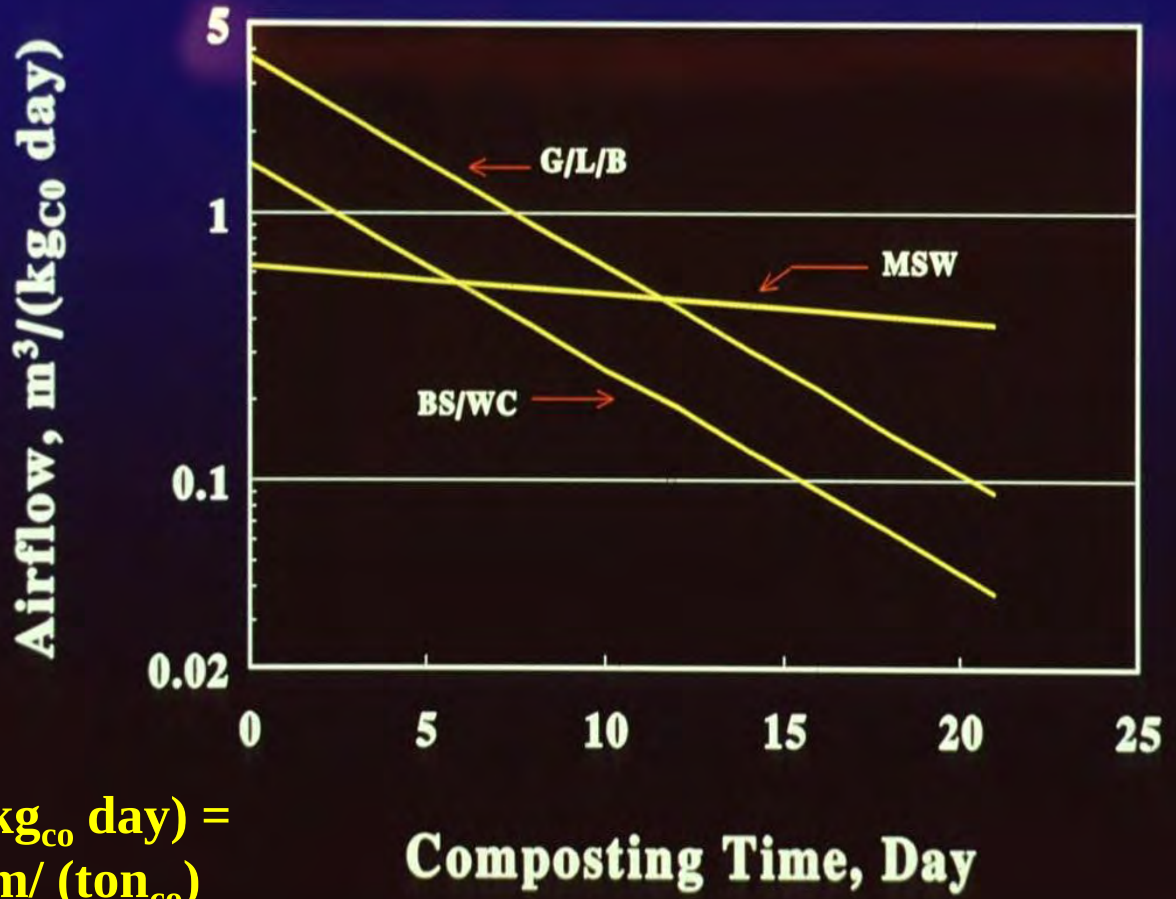
Airflow Requirements Control Temperature

$$Q(\theta) = (1 - \beta o)\, Mo \left\lfloor \frac{-khc}{\rho_a [HAO - HAI]} \right\rfloor e^{-k\theta}$$

For this equation, decomposition rate, compost equilibrium, heat of decomposition, air density, enthalpy of air (temperature, moisture), and compost maturity are the identified factors.

Keener, et al., 2002d

Airflow Requirements Control Temperature



1 m³/ (kg$_{co}$ day) = 22.3 cfm/ (ton$_{co}$)

Systems Optimization

Refer to references in paper:

Keener, H.M. 2004. Opportunities and Challenges in Composting Organic Waste. ISOR2004 Conference Proceedings. Akita Japan.

Send specific questions to: keener.3@osu.edu

Observations from Field and Computer Studies

a) Compost maturity, i.e. reduction in organic matter, must be specified when calculating system efficiency as system cost increases significantly for higher levels of maturity.

b) Optimum C/N for composting two or more products depends on decomposition rate as a function of C/N and bulk densities of materials.

c) Optimum moisture varies with material. For example:
dairy/sawdust vs biosolids/woodchips/recycle
65% vs 55%.

Observations from Field and Computer Studies (continued)

d) An ash/inert free moisture should be used to formulate mixes with high ash or inert content.

e) Facilities fixed cost can be minimized by:
   1) minimizing bulking agent;
   2) minimizing the number of aisles and alleys at the composting site;
   3) maximizing compost pile cross sectional area; and
   4) minimizing 1st stage residence time.

f) Using two-stage composting reduces cost, eg. 14-28 days stage 1 & stage 2 composting/curing.

Observations from Field and Computer Studies

g) Composting rate is maximum from 55-60 ^{o}C temperature and follows a Gaussian curve.

h) Selecting fan size to compost initially at temperatures 5-10 ^{o}C above the optimum, although slowing the process initially, can be a cost effective approach to minimize fan size, and power consumption, while minimally delaying maturity.

Observations from Field and Computer Studies

i) Sharing fans across windrows of different maturities reduces fixed and operating costs.

j) Water loss per unit dry matter loss is approximately 2/3 of the theoretical value for continuous aeration.

k) The highest rates of sustained water loss occur using continuous aeration.

Observations from Field and Computer Studies

l) Ammonia loss is proportional to airflow in the initial phase of composting.

m) VOCs disappear rapidly after start of aerobic process (if pH not inhibiting).

Using Compost for Growing Plants

Harry A. J. Hoitink

Examples of Compost Phytotoxicity Problems

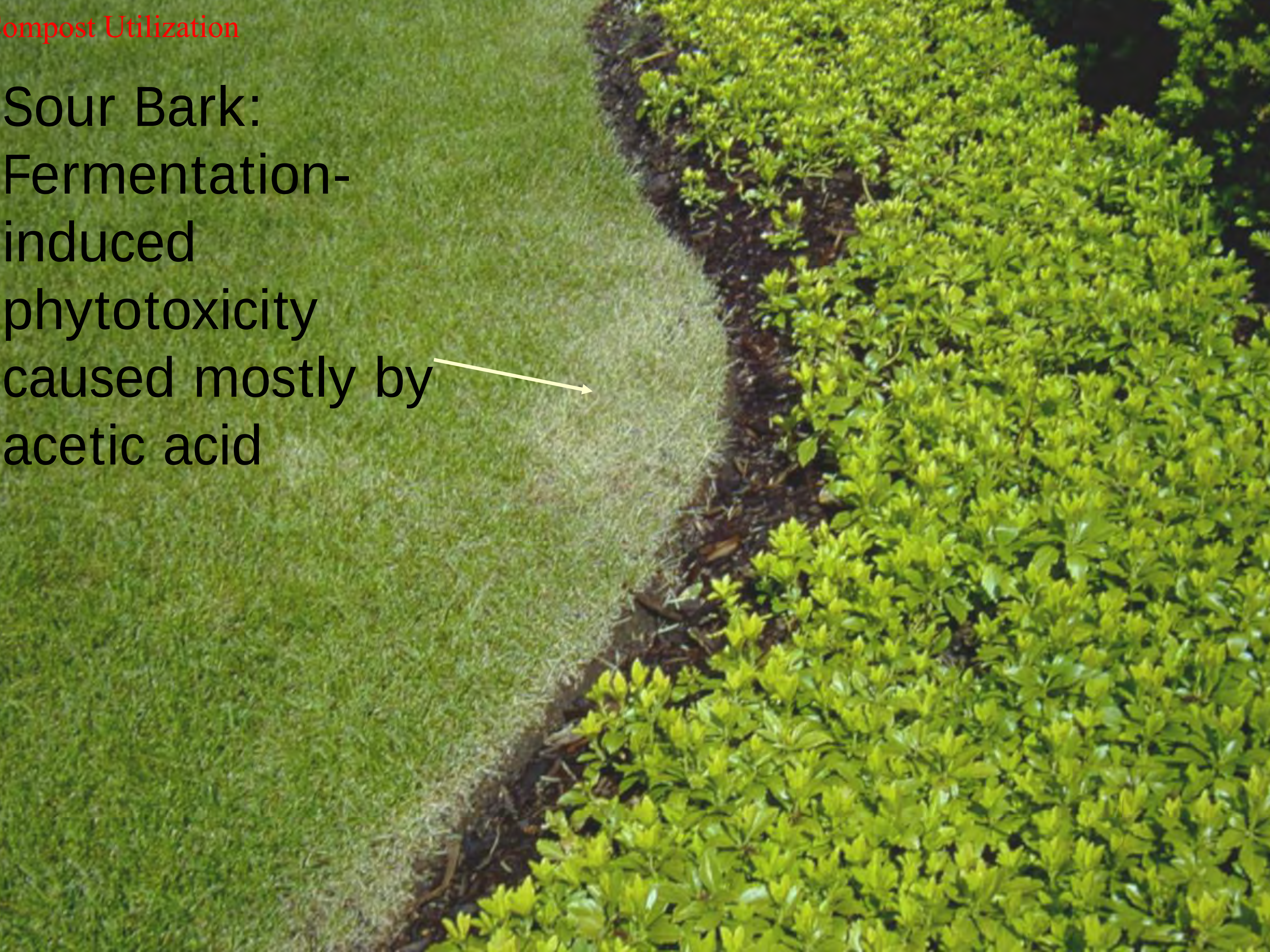
1. Fermentation acids, etc. in immature high C/N materials (eg. Sour bark, sweet or sour smell).

2. Ammonium toxicity from immature low C/N materials (eg. Composted manure, food waste, sewage sludge, ammonia smell).

3. Soluble salts.

4. Nuisance fungi causing problems in dry composts and mulches.

Sour Bark: Fermentation-induced phytotoxicity caused mostly by acetic acid



Fermentation

Cause
Composting with limited aeration in very large or wet piles.

Solution
Compost in well aerated windrows prior to use. Use mixture with low C:N ratio.

Solution
Remove compost and allow to compost/cure for 1-2 weeks in smaller aerobic windrows.


Ammonium toxicity caused by composted manure
in a low CEC soil.

Allowable Soil Soluble Salts (mMhos/cm)

Description	Saturated Media Extract	2 : 1 Dilution
Satisfactory if soil is high in organic matter, but too low if soil is low in organic matter.	Below 2	0.15 to 0.50
Satisfactory range for established plants, but upper range may be too high for some seedlings.	3 to 4	0.50 to 1.80
Slightly higher than desirable.	4 to 8	1.80 to 2.25

COMPOST STABILITY

Organic matter must be decomposed "adequately" to not:

- immobilize N
- stimulate pathogen growth

Nitrogen % and C:N Ratio of Fresh and Composted Materials

	Fresh		Composted	
	%N	C/N	%N	C/N
Hardwood Bark	0.2	200		
Sawdust	0.1	500		
Yard Trimmings	0.5	100	0.7-1.9	22-75
Biosolids	5.0	8	1.7-2.5	17
Dairy Manure	2.9	15	2-3	10-40

Plant Response versus Age of Composted Dairy Manure + Straw or Sawdust

Developments in Disease Suppression and Plant Growth using Composts

Harry A. J. Hoitink

Compost Induced Plant Disease Suppression

I. General (Natural) Suppression (90% of mature composts)
- Phytophthora root rots
- Pythium root rots

II. Specific suppression (20% of composts)
- Rhizoctonia root roots

III. Induced systemic resistance (2% of composts)
- Foliar diseases

Factors Affecting Compost Suppression of Plant Diseases

- Heat kill (Pathogens, beneficial microorganisms, weed seeds, etc.)

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

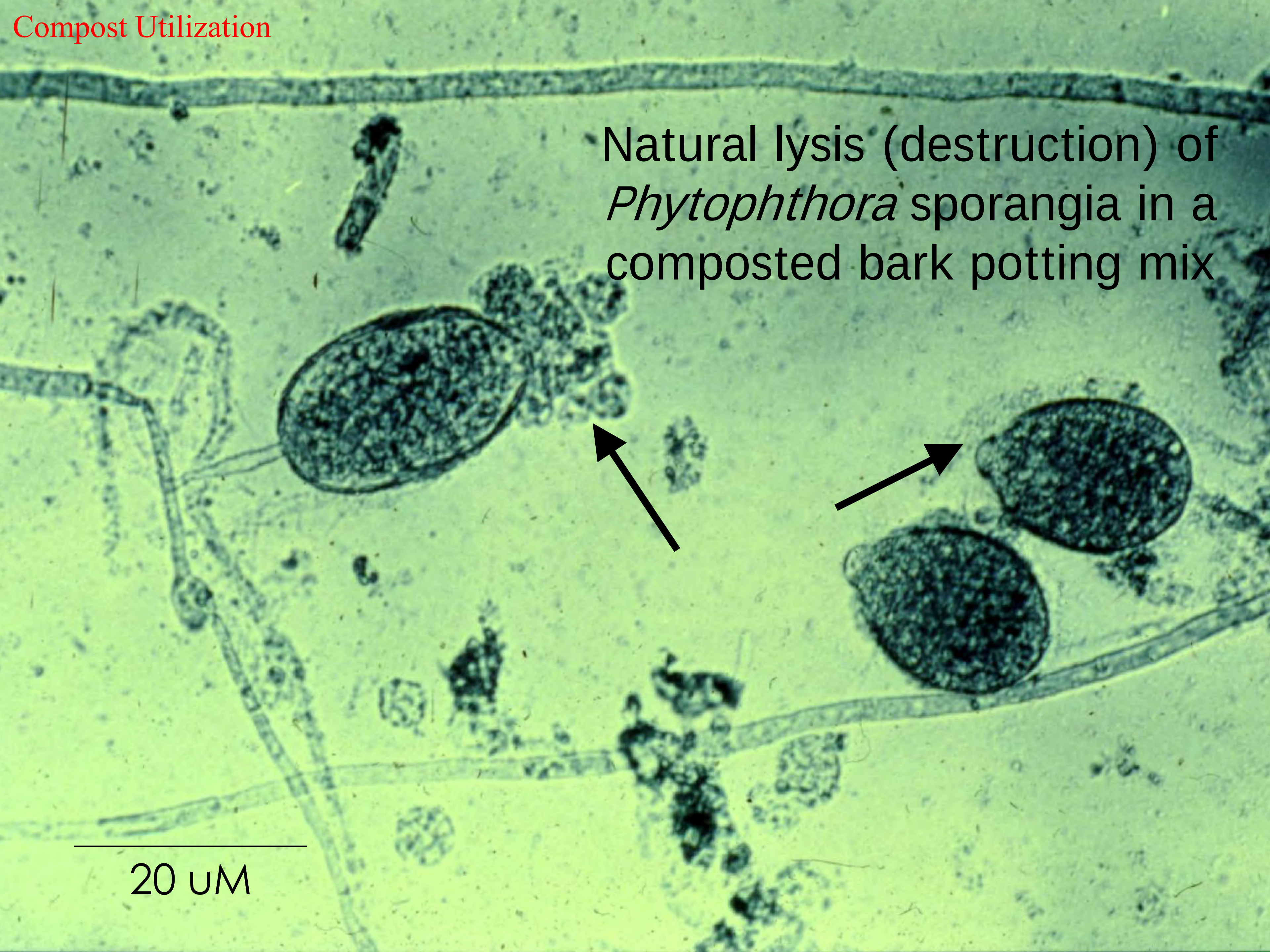
- Recolonization by microbes after peak heating

- Chemical and physical factors

Each temperature zone in a compost pile has its own characteristic microflora. During curing, high temperature microorganisms are replaced by lower temperature soil microorganisms, some of which control *Phytophthora* and *Pythium* root rots.

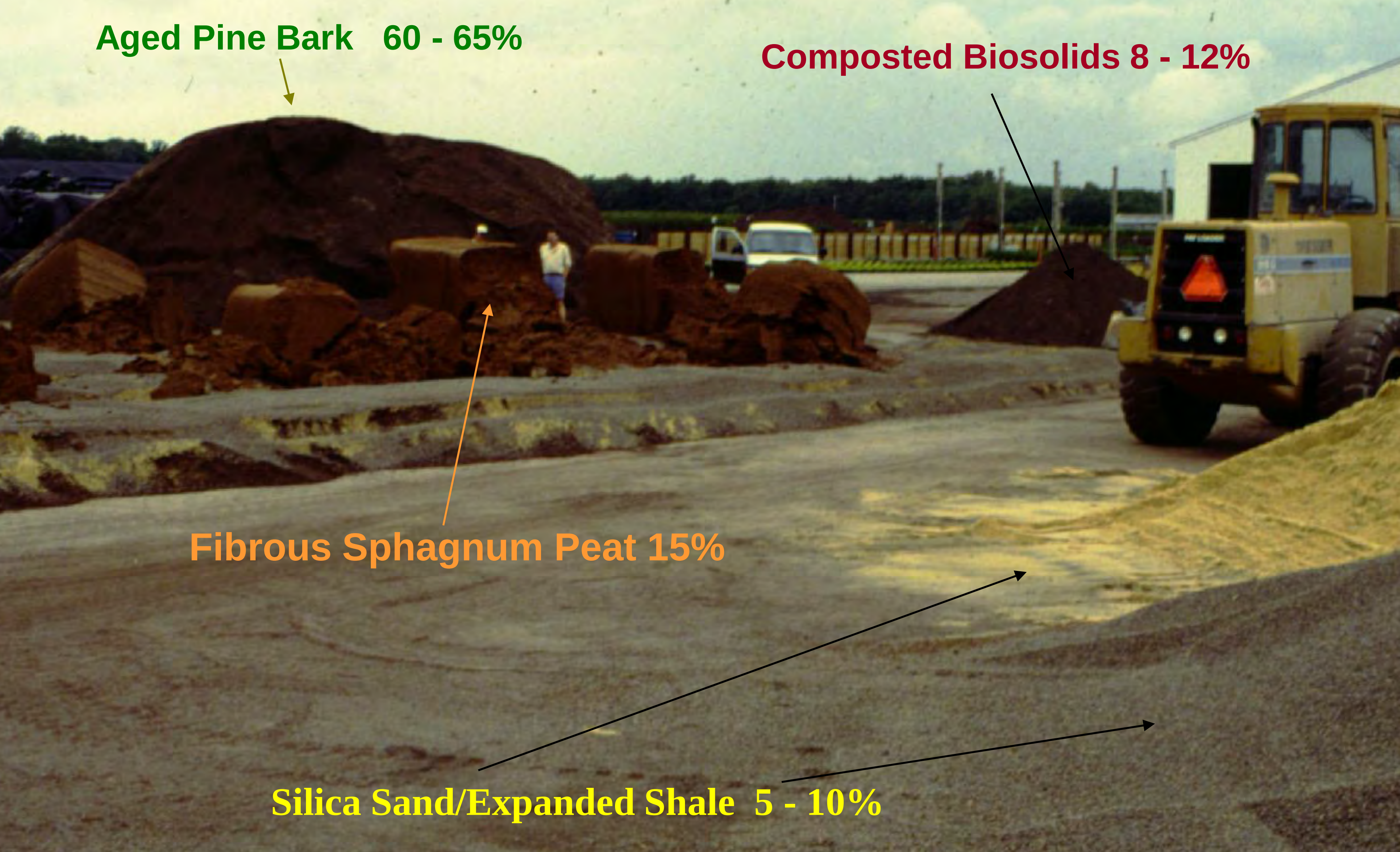
This Phytophthora root rot bioassay helped prove that natural suppression in compost mixes is effective.

Spring et al., 1980, Phytopathology 70:1209-1212

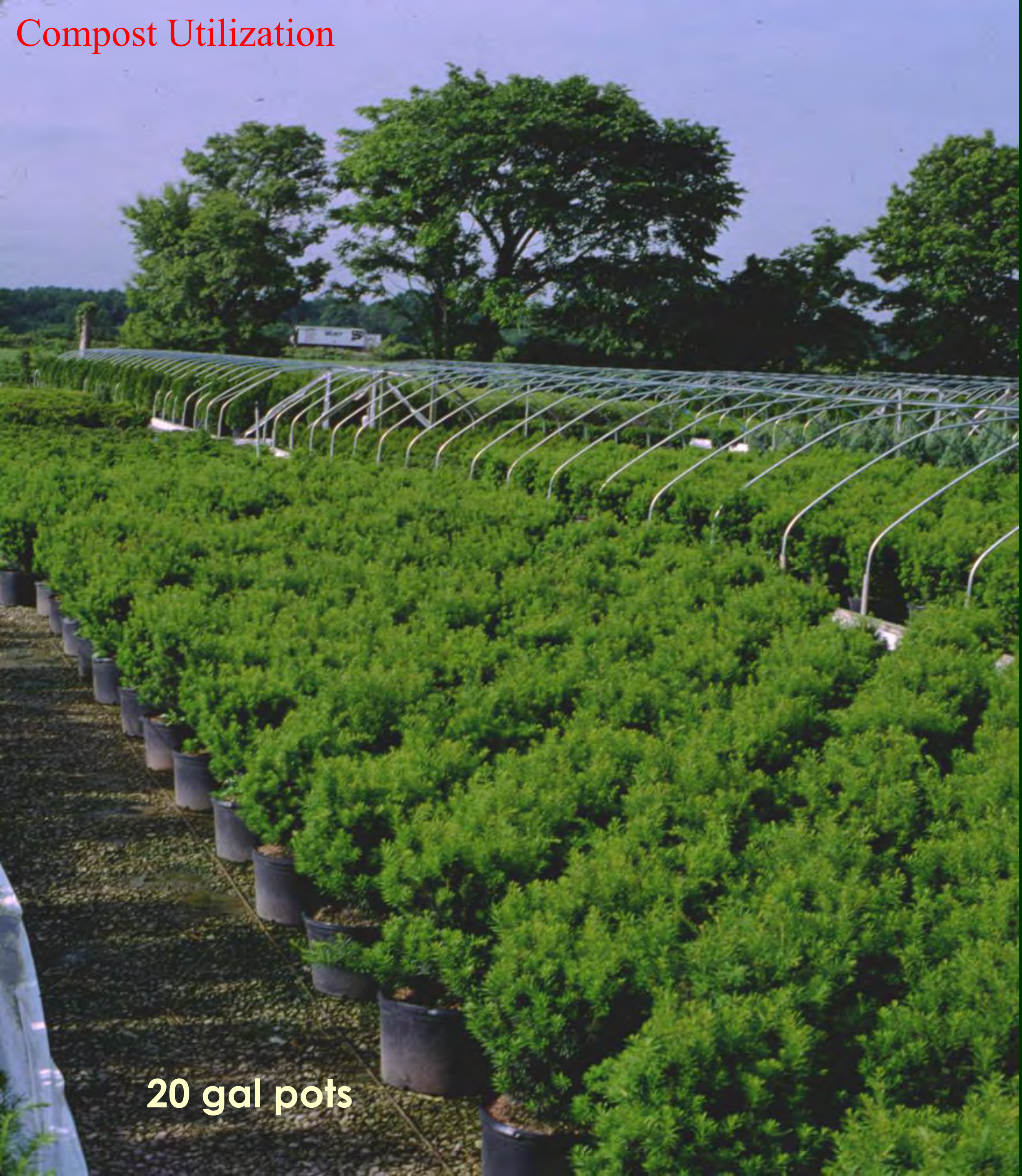

Natural lysis (destruction) of *Phytophthora* sporangia in a composted bark potting mix
20 uM

NATURAL SUPPRESSION

Blending materials for disease suppressive potting mix.



Suppressive potting mix used to control root diseases in potted poinsettia plants.



Seven-yr-old Taxus crop transplanted at 1-1.5 yr intervals to sustain natural suppression of root rot. Fungicides are not used in spite of its extreme susceptibilty to Phytophthora root rot!!!!

Pot–in-pot systems allow natural suppression to be used to produce root disease free trees.

Rhododendrons in naturally suppressive compost amended mix

What about other diseases?

Why was Rhizoctonia not suppressed in the mix that controlled Phytophthora?

- *Rhizoctonia is* a very common pathogen in soil that produces large 1-2 mm diameter structures.
- Such large pathogens are not suppressed by bacteria that commonly colonize composts and control *Phytophthora*.
- Specific biocontrol agents that naturally suppress Rhizoctonia do not consistently colonize composts after peak heating!

Suppression of *Rhizoctonia*

More than 80% of 300 different compost-amended potting mixes tested failed to suppress Rhizoctonia damping-off because specific biocontrol agents failed to colonize the compost naturally!!

The solution is to inoculate potting mixes during formulation with biocontrol agents (eg *Trichoderma* spp.) that destroy *Rhizoctonia.*

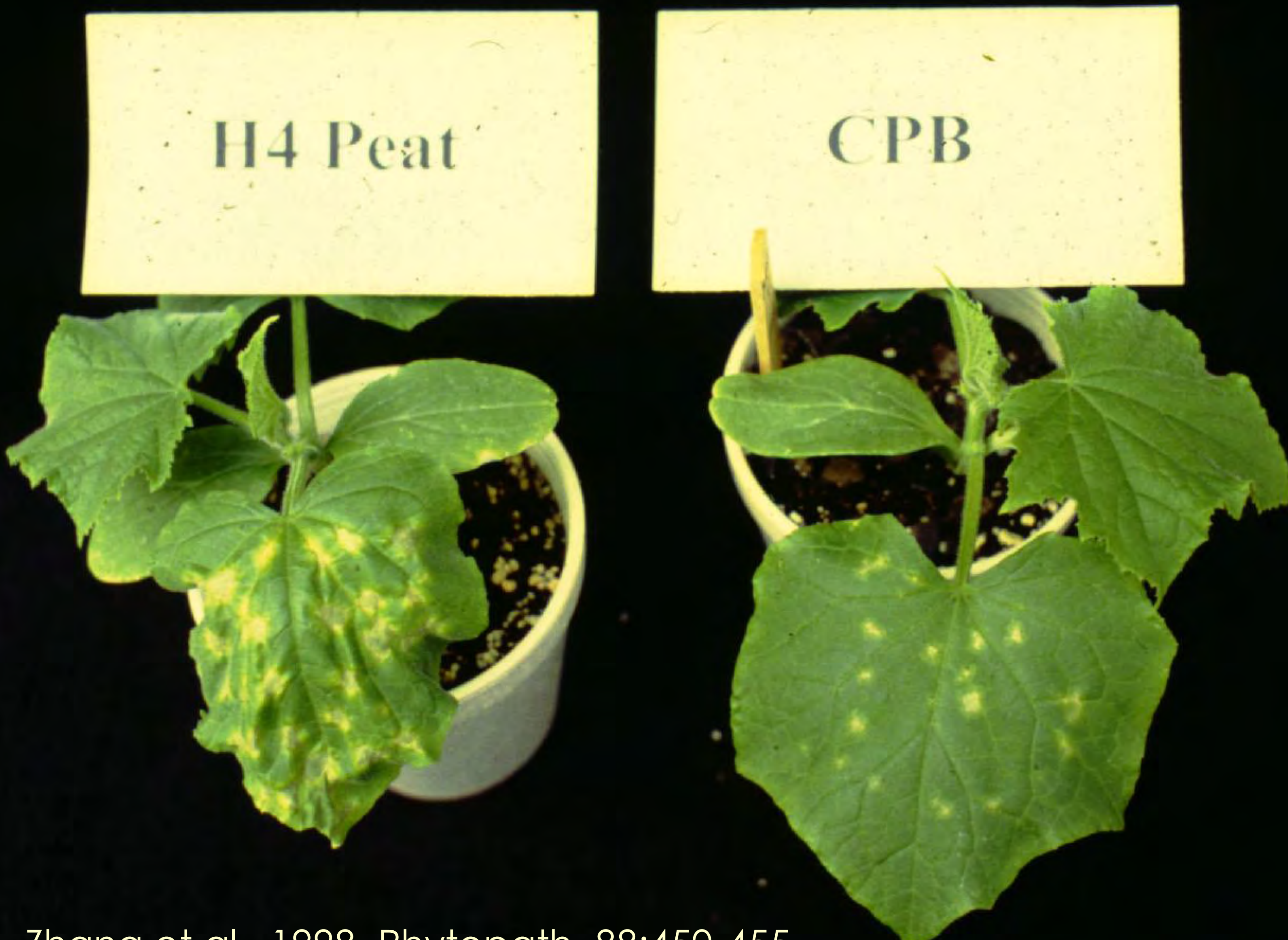
Compost-Induced Systemic Resistance (ISR)

- Less than 2% of all types and batches of composts tested naturally induced ISR.

- Specific *Bacillus* strains and *Trichoderma* isolates are the most ISR-active microorganisms in composts.

Krause et al, 2003, Phytopathology 93:1292-1300.

Compost-Induced Systemic Resistance (ISR)



Zhang et al., 1998, Phytopath. 88:450-455

Horst et al., 2003 Phytopathology 93: S37

- ISR induced by T382 is more effective in compost-amended than in peat potting mixes.

- The same has been reported for control of *Fusarium* crown rot of tomato and for *Phytophthora* blight of cucumber.

•Pharand et al, 2002, Phytopathol. 92:424-438

•Khan et al, 2004, Plant Dis. In Press.

Can ISR be scaled up commercially??

Examples:

- Phytophthora blight on Rhododendron
- Leaf spot on Rhododendron
- Botryosphaeria on *M. pennsylvanica*
- Fusarium wilt of Cyclamen
- Anthracnose of Euonymous

2003 Phytophthora Blight/Dieback Trial, Willoway Nursery, Huron

- Plant: Rhododendron cv English Roseum
- Treatments: *T. hamatum* 382 and control
- Reps: four of ~120 each
- Planted Oct. 2002; rated Sept, 2003
- All plants treated 5x with Aliette and 3x with Subdue from May 15- Sept. 15


T382
Control
T382


Control
T382

Suppression of Phytophthora Dieback on Rhododendron cv English Roseum induced by Trichoderma hamatum 382

	Disease Severity [a]			
	Dieback (%)		Plants Killed (%)	
Treatment	**Mean**	Std.Dev.	**Mean**	Std.Dev.
Control	**16.9**	11.8	**4.2**	4.4
T382 [b]	**6.3**	5.1	**1.1**	1.3
	$p = 0.05$		$p = 0.002$	

Induced Systemic Resistance Conclusions

- ISR-active microorganisms must be introduced into composts for consistent efficacy.
- Substrate matters! Pyrolyzed or very old composts do not support ISR!

Example of Pyrolyzed or very old composts which would not support ISR!

Overall Conclusions

- Compost stability, nitrogen status and the presence of phytotoxic compounds are important indicators of compost quality for value-added markets.
- The highest value markets require quality composts and expert knowledge of potting mix formulations and production technology to produce diseases suppressive mixes.
  - Biological control of root diseases with composts by natural suppression is practiced widely.
  - Specific suppression requires inoculation.
  - Some foliar diseases controllable by ISR-active composts.
  - ISR still is a novel field of science.

Thank you!

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