

Disease suppression in the composting process

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Compost

- DD?
 - Webster's 2nd College Edition:
 - -*n* A mixture of decomposing vegetable refuse, manure, etc., for fertilizing and conditioning the soil
 - -*vt* To convert (vegetable refuse) into compost
 - Mulch?
 - Leaves, straw, peat moss, etc., spread on the ground around plants to prevent evaporation of water from soil, freezing of roots, etc.



Process variables

- Main variables
 - Moisture content
 - C:N ratio
 - Ambient temperature
 - Open versus closed container
 - Turning frequency
 - Pile size
- Secondary variables
 - Feed stock
 - Process type
 - Turned windrow
 - Forced air static pile
 - Turning type
 - Urban / Rural location
 - Curing time
 - Post process inoculation

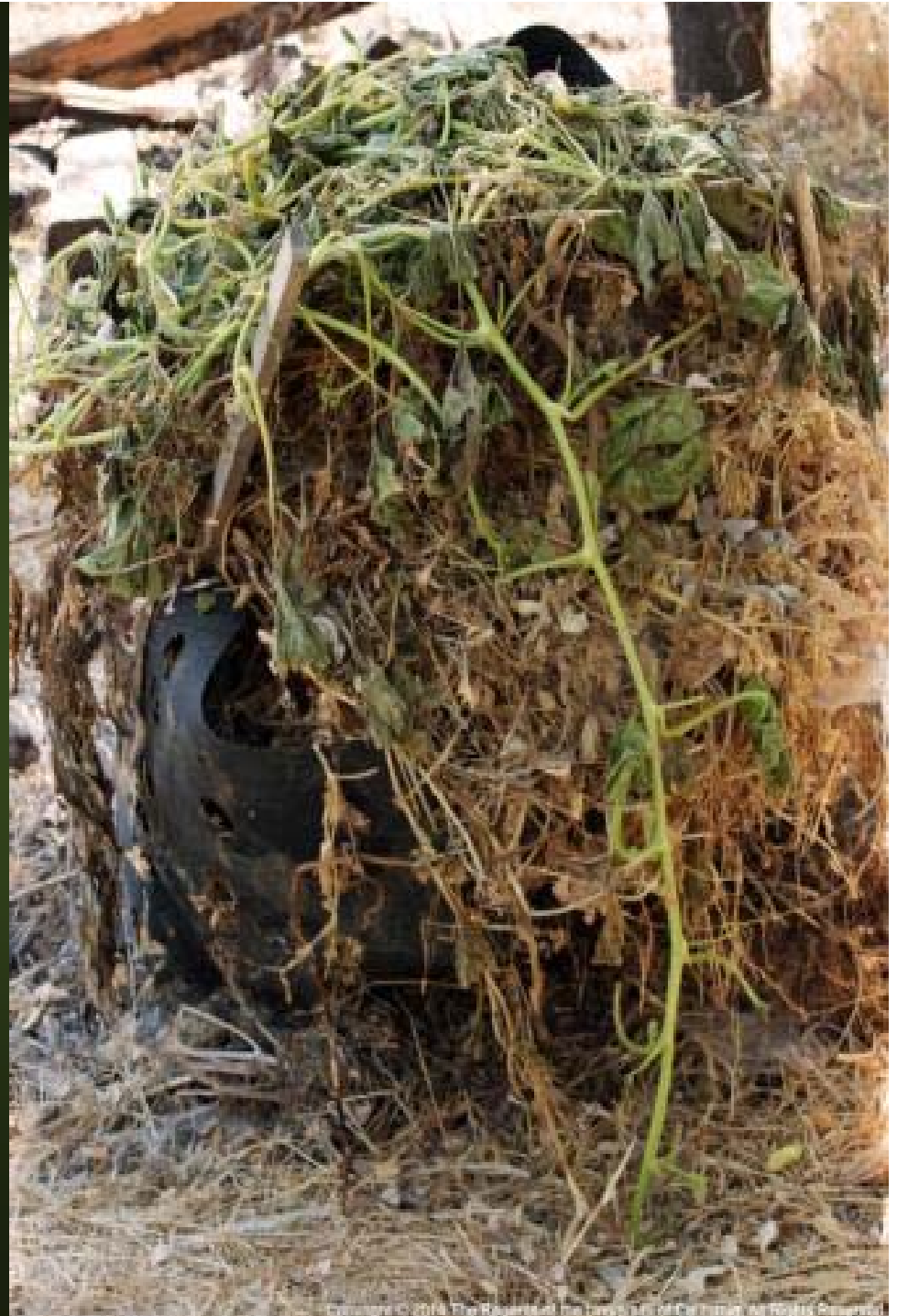
Temperature

- Pile size drives this
- $\sim 1\text{m}^3$ threshold
 - If everything else is right



Temperature

- Pile size drives this
- $\sim 1\text{m}^3$ threshold
 - Cold composting
 - Small piles
 - Turned by hand
 - Biological / chemical pathogen destruction
 - Kills some microbes
 - Yuen & Raabe, Plant Disease, 1984



Temperature

- Pile size drives this
- $\sim 1\text{m}^3$ threshold
 - Hot composting
 - Big piles
 - Above methods + thermal destruction
 - Kills virtually all microbes
 - Some viruses and prions escape
 - For the most part, these exceptions are non-issues



Temperature

- Why do we care?
 - DD of compost
 - Can include:
 - Animal manures
 - Biosolids
 - Infected plant material
- Pre 1940's container media (nurseries)
 - Aged peat moss
 - High % organic matter loams
 - 1960's, hard to find



Temperature

- Nursery Industry
 - Tries compost
 - Hoitink et al (1976) ...
Composted Hardwood Bark
- Compost
 - Noun
 - Plant and human health concerns
 - Verb
 - US EPA regulates commercial process
 - 40 CFR Part 503



Temperature

- Time requirements vary by composting process
 - Always at 55°C
 - 131°F



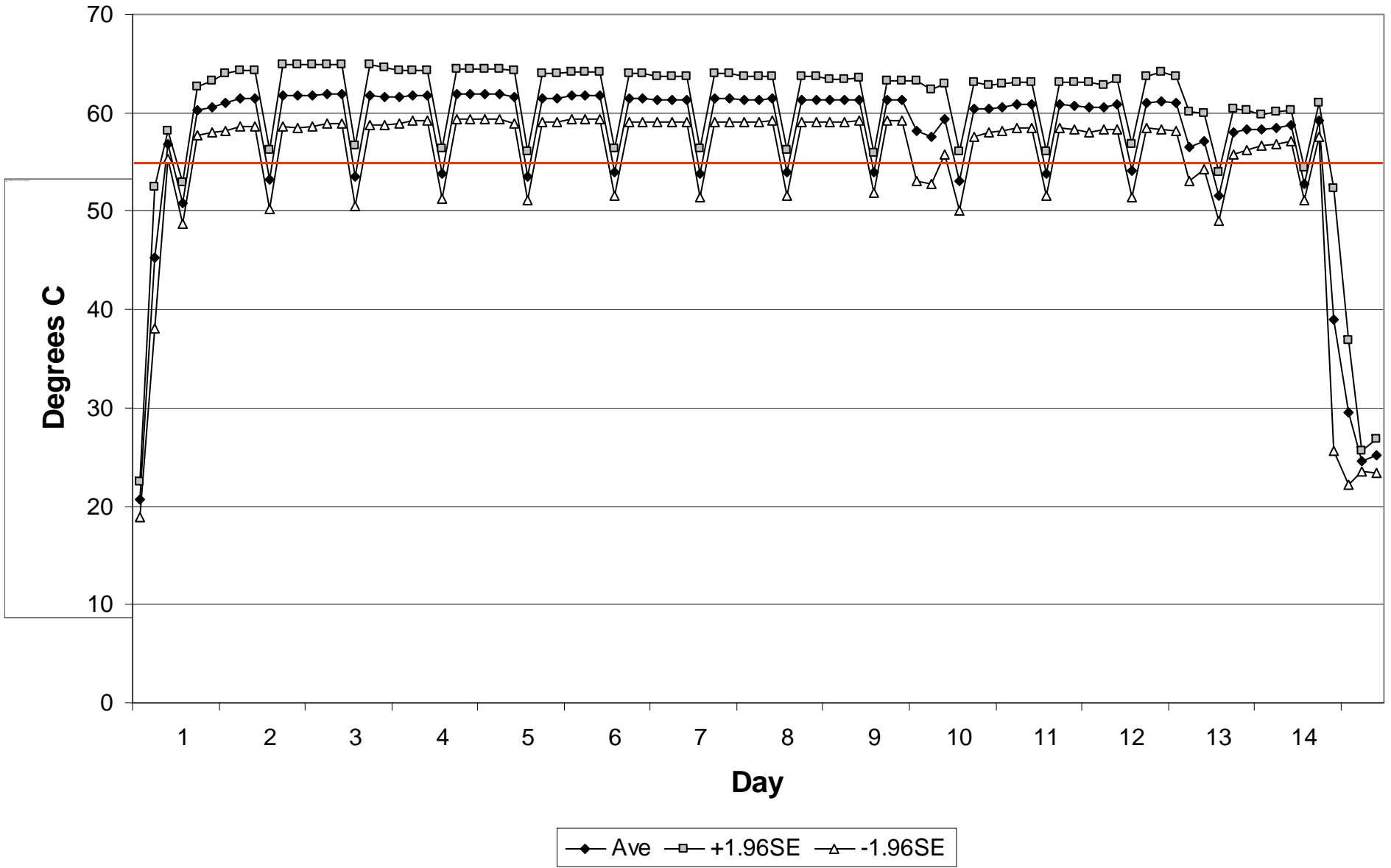
Commercial Composting Processes (bay area)

- “Traditional” composting method
- Turned by various types of machinery

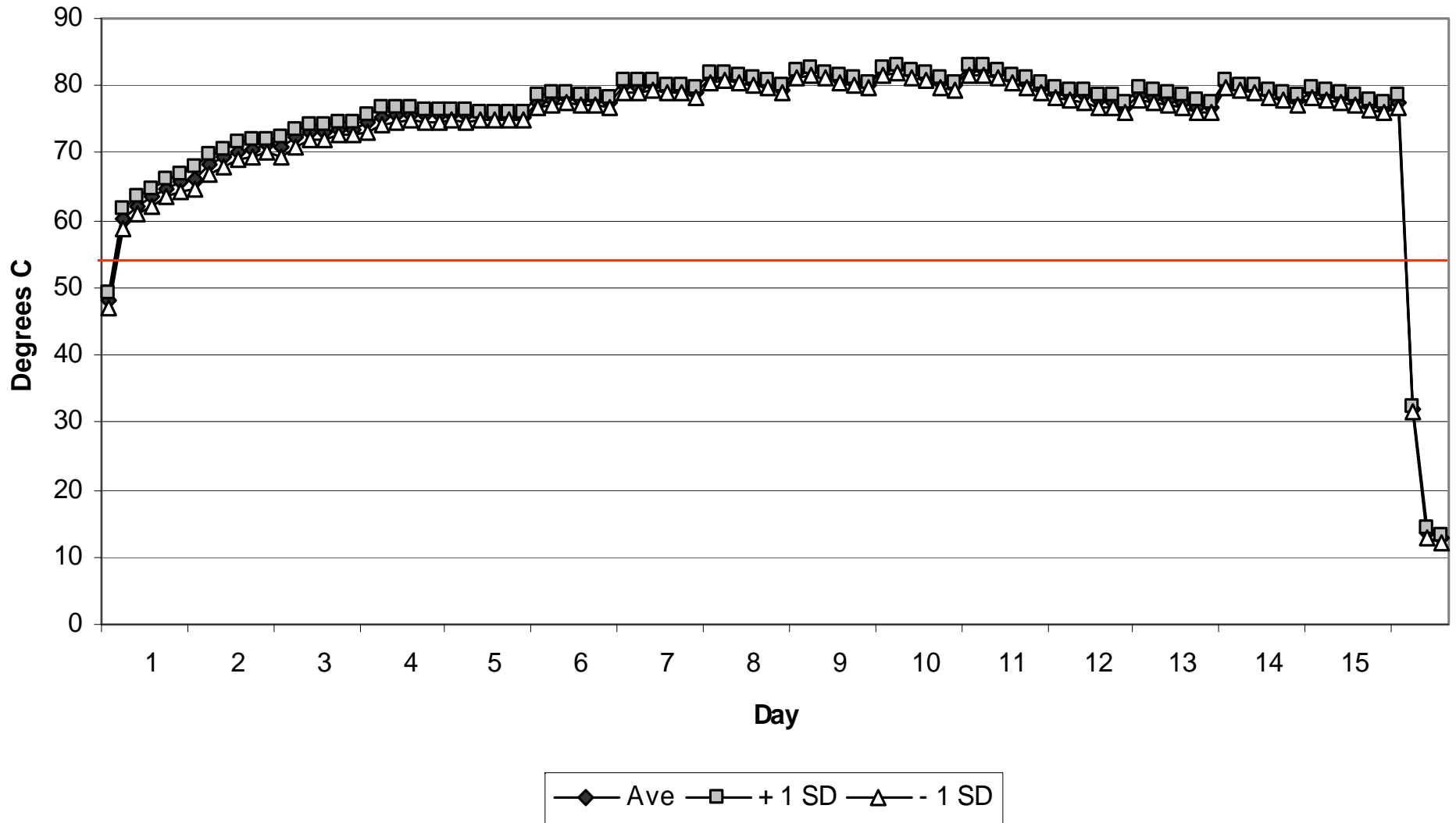
- No turning
- Air forced in by blowers



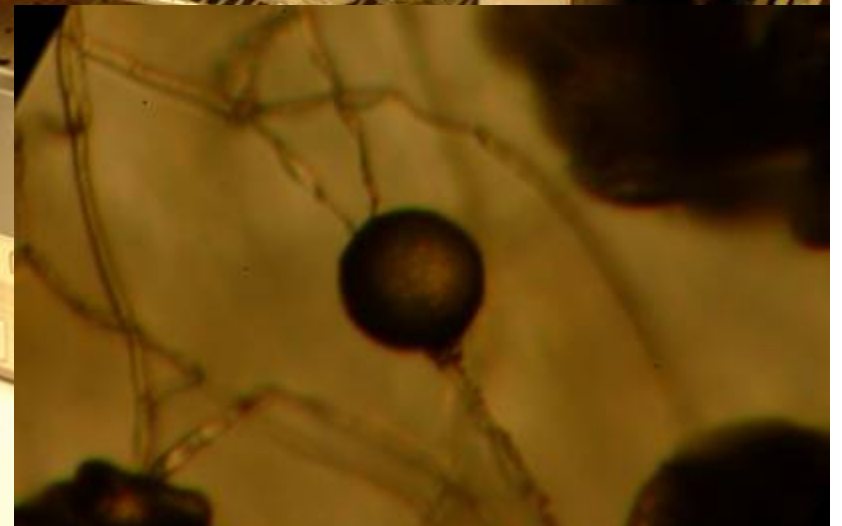
Average Bolinas Compost Temperature by Day



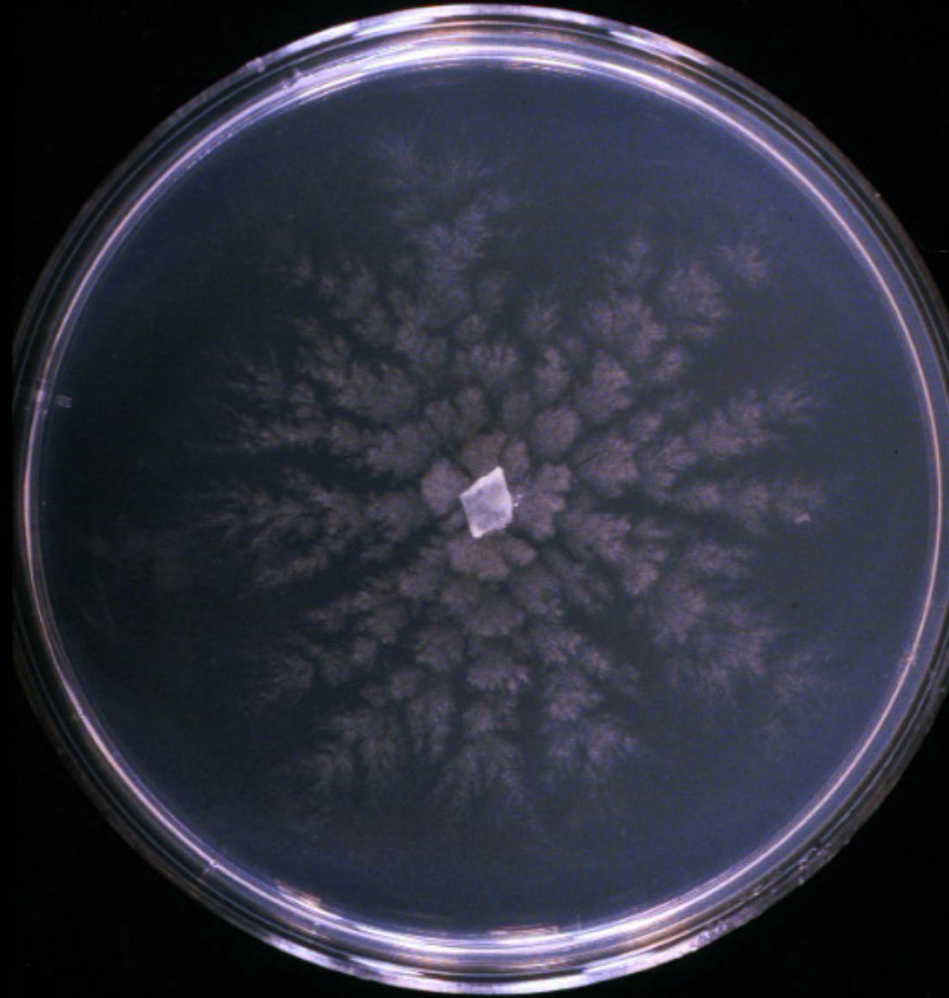
Average Forced Air Composting Temperatures



Heat Treatment of *P. ramorum* on Natural Substrates



Heat Treatment of Pure Culture



Time to Mortality

55 deg C



45 deg C



40 deg C



Lower temperatures did not cause mortality within the experimental time frame

Curing time

- None technically required
- Young (low curing times, typically <1 wk)
 - Low biodiversity, high chemical diversity
 - Recolonization easy(ish)
- Mesic (1-4 weeks)
 - High biodiversity, recolonization in process
 - Most reactive chemicals stabilized
- Mature (^ curing times, typically >4 wks)
 - Moderate biodiversity, chemically homogenous and stable
 - Recolonization finished
- NOTE: These times vary with location & climate

The problem with mulch

- No formal definition of product or process
 - Mylar
 - shredded reflective plastic for thrips control
 - Sheet mulching
 - Newspaper/cardboard/manure/wood chip lasagna
 - Wood chips
 - Straight from chipper
 - Pallets
 - BUT fresh wood chips can self-compost
 - Especially if chipped with leaves (unregulated?)



<http://onelittlefarm.blogspot.com>



Compost as a cure?

- Harry A.J. Hoitink at the Ohio State U.
 - Composted green-waste (bark) is disease suppressive in potting mixes (1970's – 2009+)
 - Bacillus, Trichoderma, etc.
 - e.g.: http://plantpath.osu.edu/sites/plantpath/files/imce/files/Hoitink/BioCycle_2009.pdf
- The Ashburner system: Guy Ashburner (Australian avocado grower, 1970's)
 - cover crop / mulches, and amends soil beneath trees
 - Reduces *P. cinnamomi* infections after several years
 - Ref: Magdoff F. & Weil R.R. (2004) Soil Organic Matter in Agriculture, CRC Press, p.162
 - Adopted wholesale by Australian avocado industry

Will compost disinfect my soil?

- Field efficacy
 - Results all over the board
 - Product consistency
 - Process is regulated (kills most pathogens)
 - Product is not regulated (may not be effective vs pathogens)
 - Suggestions for post-process inoculation
 - Trichoderma, other bio-fungicides
 - Cost is already a factor
 - Full circle?
- Giles Hardy and others show that some (many?) soilborne *Phytophthora* species can survive in finished compost

Can *P. ramorum* survive the composting process?

- Federal quarantine on *P. ramorum*
- Composting industry subject to quarantine
- We prove composting eradicates
 - Cultural methods to assess contagion
 - DNA methods to assess survival
- Properly processed compost should be exempted from quarantine

Phytophthora ramorum

- Sudden Oak Death
- Rain, wind, water dispersed
- Devastating to oak trees and relatives
- Large host list
 - Many landscape species
- Believed to be introduced

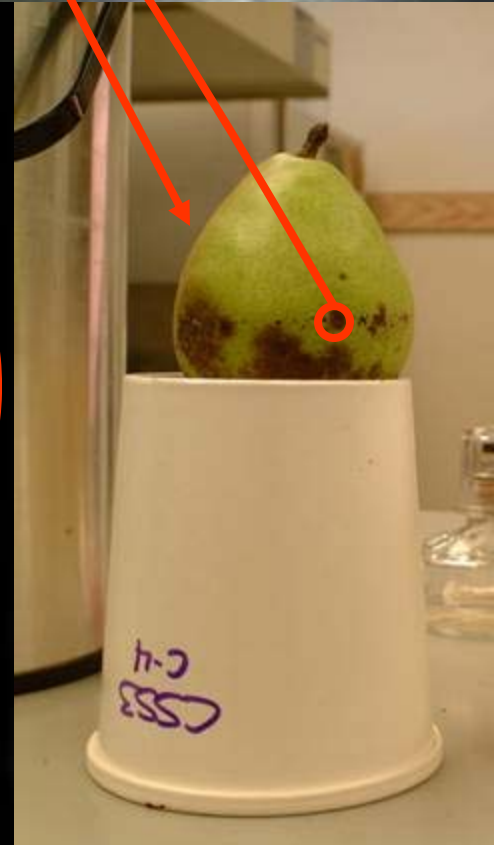


P. ramorum and composting

- More than 50,000 tons composted per day in California
- Composting effective against other diseases
- USDA & CIWMB requested study
 - Validate quarantine or
 - Provide exemption



Cultural methods: Direct Plating vs. Baiting

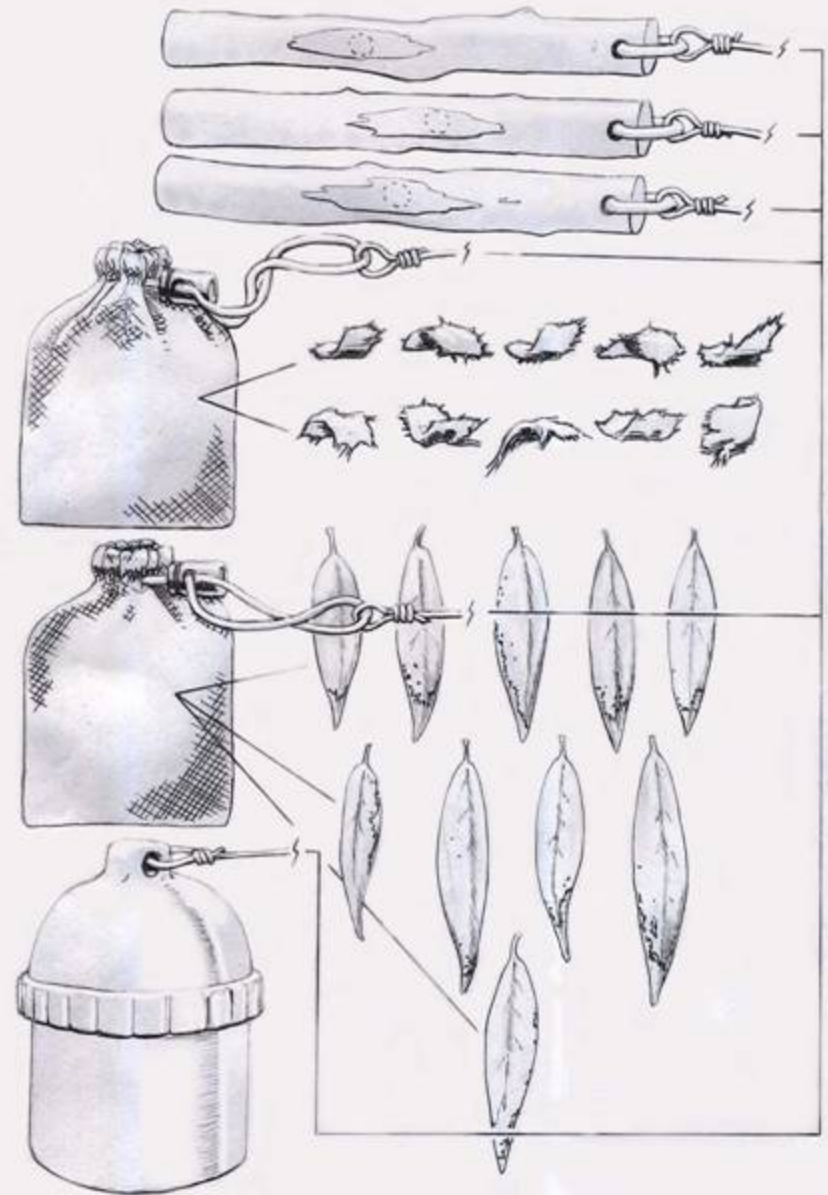


Method depends on substrate



Can composting do the job?

- “Direct Process Evaluation”
- Test probe composition:
 - 3 Stems
 - 10 Chips (mesh bag)
 - 10 Laurel leaves (mesh bag)
- Temp. Recorder
- 4x in each pile



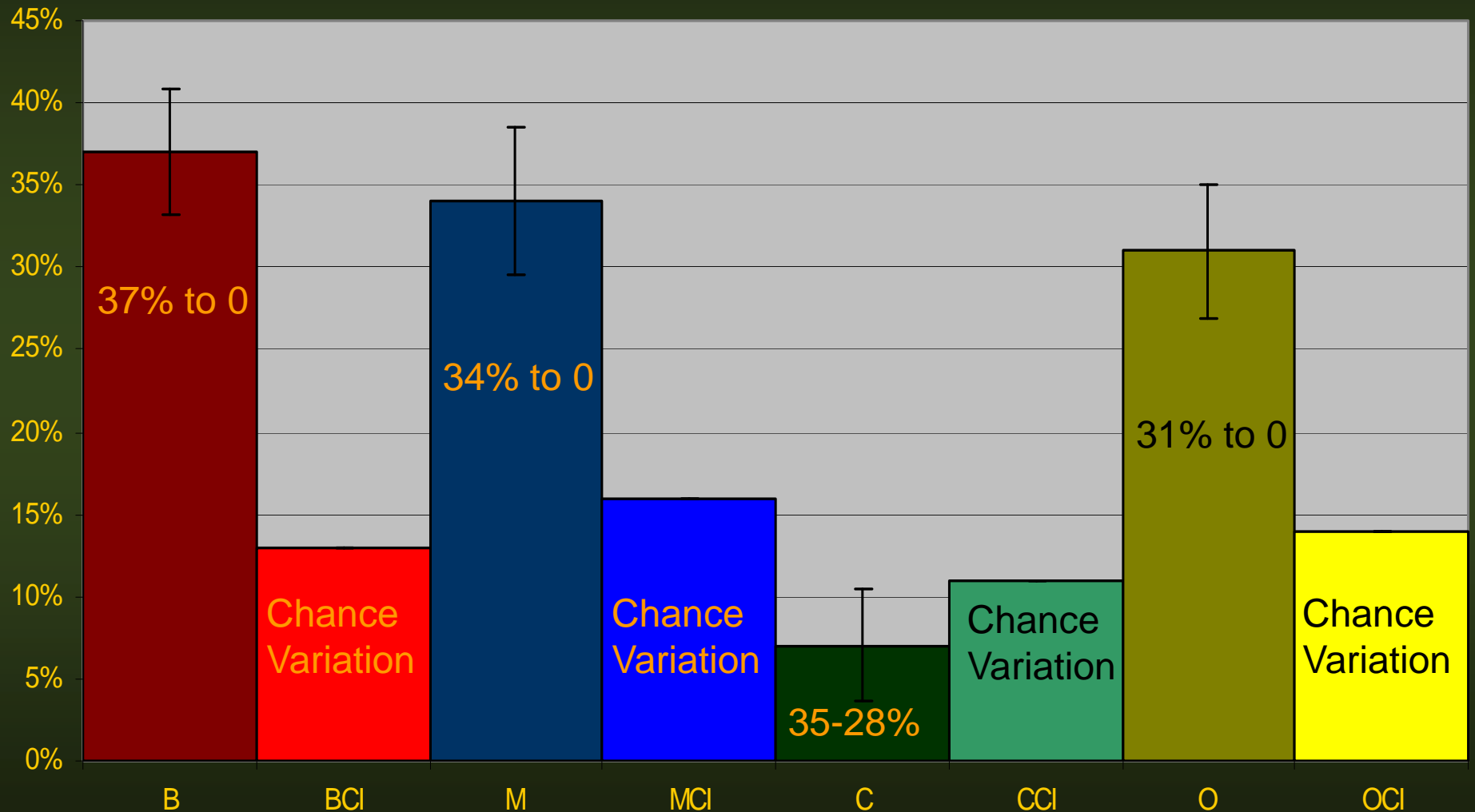
Turned Windrow and Oven Results by Site

Site	n	Pre	% Pre	SE	Post	% Post	SE	Delta mean	SEdiff	99% CI for 0
B	8	66/180	37%	3.85%	0/180	0%	0.00%	-37%	3.85%	0 +/- 13%
M	8	61/180	34%	4.49%	0/180	0%	0.00%	-34%	4.49%	0 +/- 16%
C	8	63/180	35%	3.08%	50/180	28%	1.38%	-7%	3.38%	0 +/- 11%
O	8	52/168	31%	4.03%	0/168	0%	0.00%	-31%	4.03%	0 +/- 14%

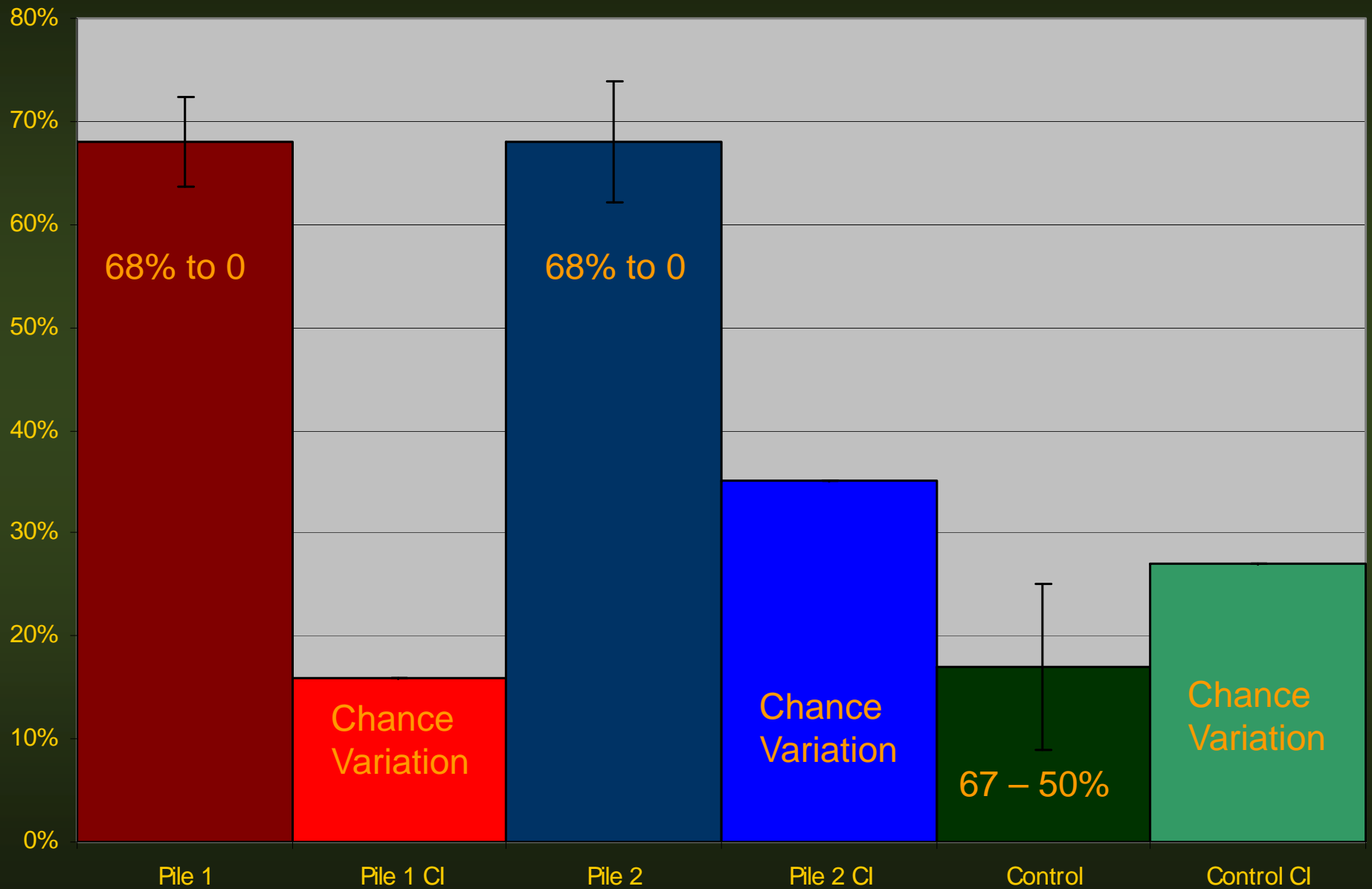
Forced Air Static Pile Results

Pile	n	Pre	%Pre	SE	Post	%Post	SE	delta mean	SEdiff	99% CI for 0
1	8	125/184	68%	4.45%	0/184	0%	0.00%	-68%	4.45%	0 +/- 16%
2	4	63/92	68%	5.95%	0/184	0%	0.00%	-68%	5.95%	0 +/- 35%
C	8	123/184	67%	2.40%	92/184	50%	7.79%	-17%	8.15%	0 +/- 27%

Turned Windrow and Oven Results by Site



Forced Air Static Pile Composting Results



Oven and Compost Trial Conclusions

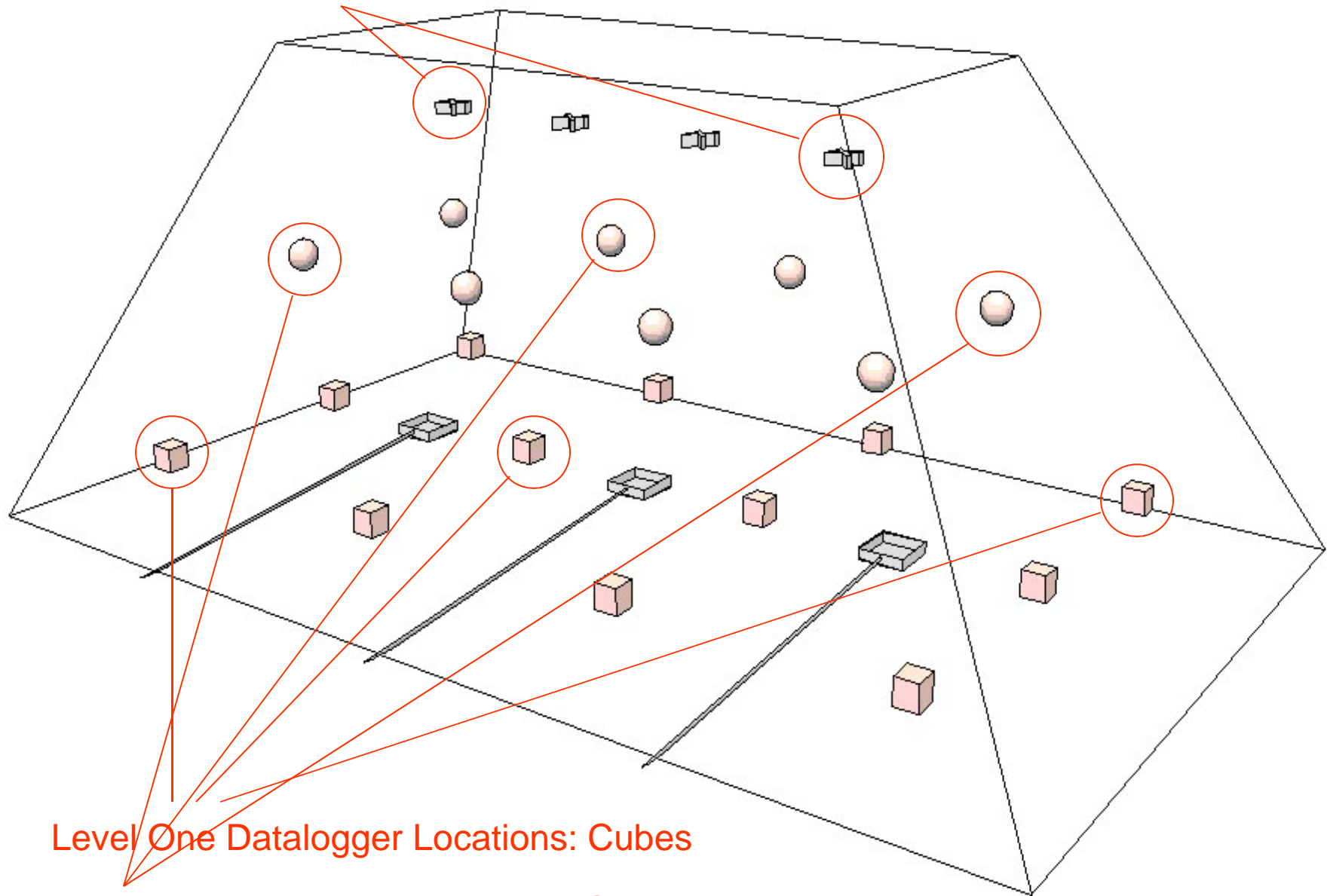
- Composting is capable of eliminating *P. ramorum* from green-waste
 - Cal. Integrated Waste Mgmt. Board guidelines
- Heat alone is sufficient to kill *P. ramorum*
 - Biotic and chemical interactions may augment the kill rate

Is it effective?



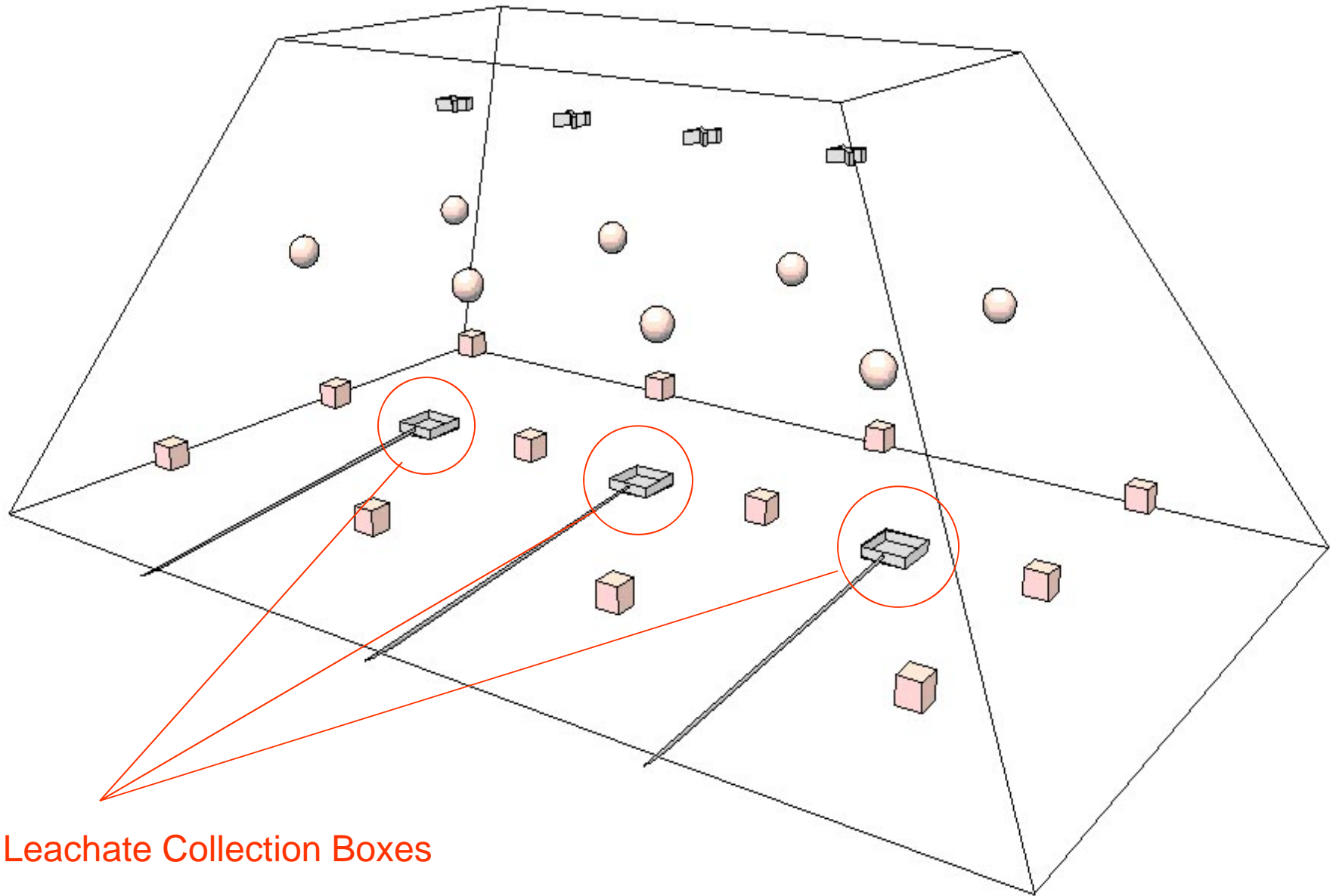
- “Spot Test Evaluation”
- Large compost pile
 - 10% artificially inoculated bay leaves
 - Estimated equivalent of 30% naturally infected material
- Cultural tests (contagion)
 - Runoff collection
 - Flooding
 - Sentinel plants 1-15m around compost pile
 - Planting Rhodies in finished compost
- DNA detection (presence)
 - Comparison of DNA levels beginning and end

Level Three Datalogger locations: "X"s



Level One Datalogger Locations: Cubes

Level Two Datalogger Locations: Spheres



Leachate Collection Boxes

Runoff collection

- Test contagion in rain
- Collection after limited irrigation
- Pear bait collected water
- Turn pile to dry and aerate





- Flood sampling: tests contagion in water
 - $\frac{1}{2}$ of pile flooded in pools
 - Drained
 - Pear baited



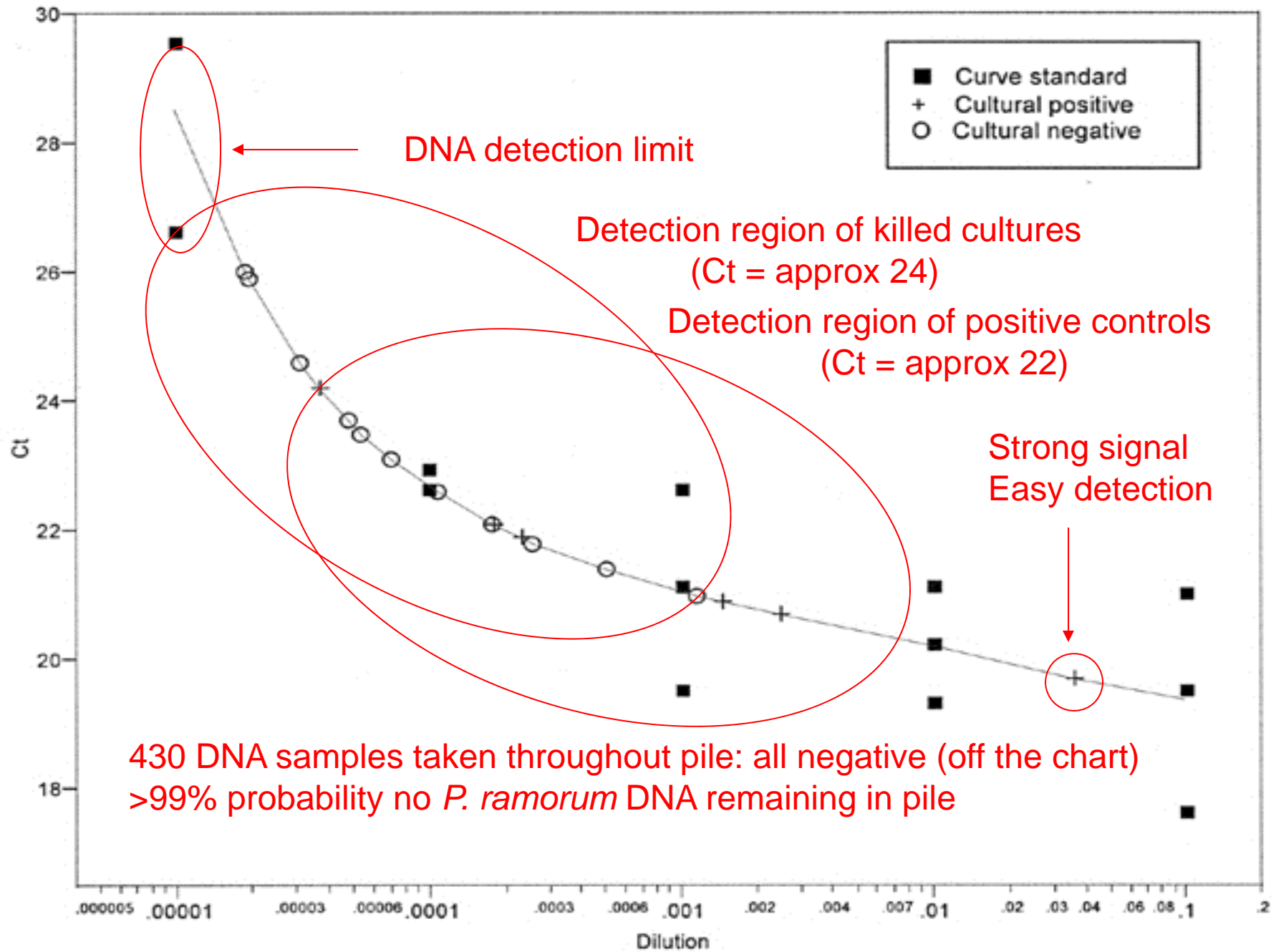


Planting tests

- Tests contagion in planting material
- Sentinel Rhodies planted in compost
 - After pile disassembled
- Leaves and stems evaluated for symptoms
- Any symptoms found are plated and baited

Cultural test Results

- All 48 direct samples from the pile were negative
- All runoff tested negative
- All 120 flood samples tested negative
- All 248 direct plating and 36 pear baitings of sentinel plant leaves tested negative
- After three months from experiment end, all planted rhododendrons tested negative





Conclusions

- Contagion risk from wind, water, or finished compost undetectably low
- DNA levels at end of process undetectably low
- Composting effectively eliminates *P. ramorum* from greenwaste
- Compost contagion risk negligible

Okay, but what if it gets infected afterwards?

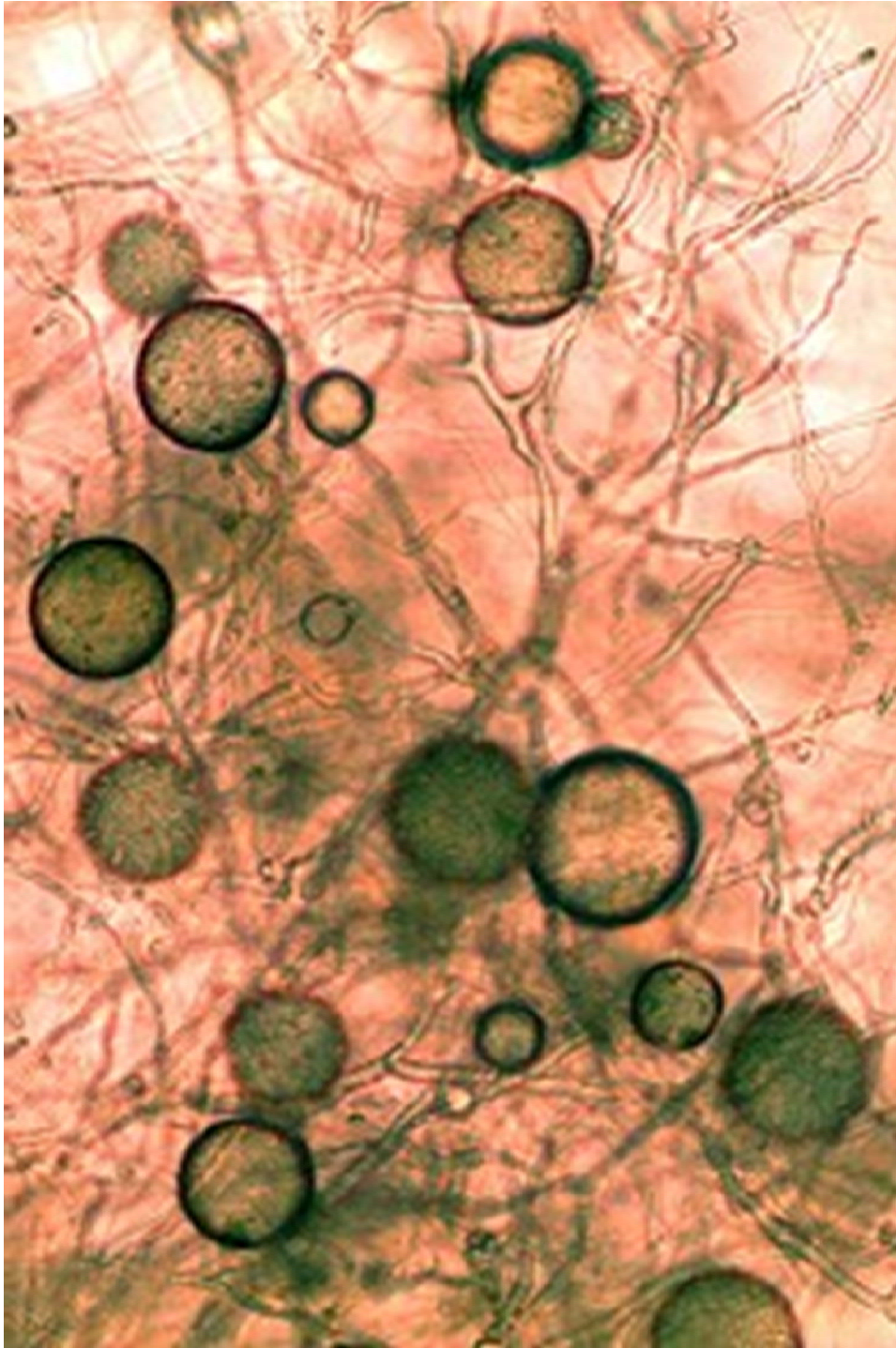
- Article in California Agriculture on *Phytophthora ramorum* infesting finished compost
 - Somewhat esoteric angle on the subject
 - <http://californiaagriculture.ucanr.edu/landingpage.cfm?article=ca.v069n04p237&fulltext=yes>
- Perhaps more relevant article in the Journal of Applied Microbiology
 - More comprehensive study, and sort of a basis for the newer article
 - <https://nature.berkeley.edu/garbelotto/downloads/Swainetal.pdf>



Image: Don Barr, bsu.edu

Spore types

- Oospores
 - Sexually produced survival structures (~seeds)
- Chlamydospores
 - Asexual survival structures
- Sporangia
 - Delicate football shaped dispersal structures
- Zoospores
 - Delicate hunting spores



Spore types

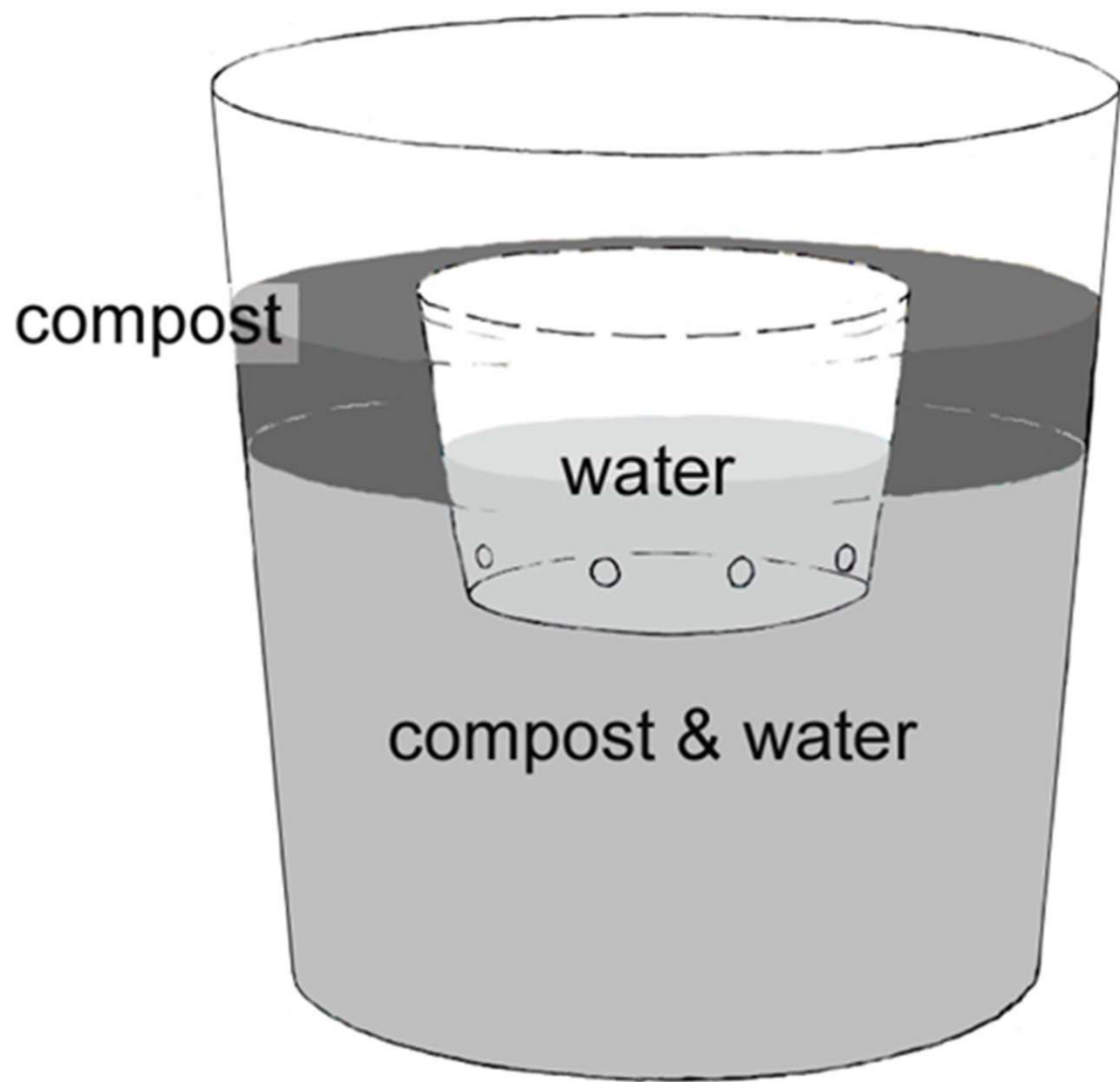
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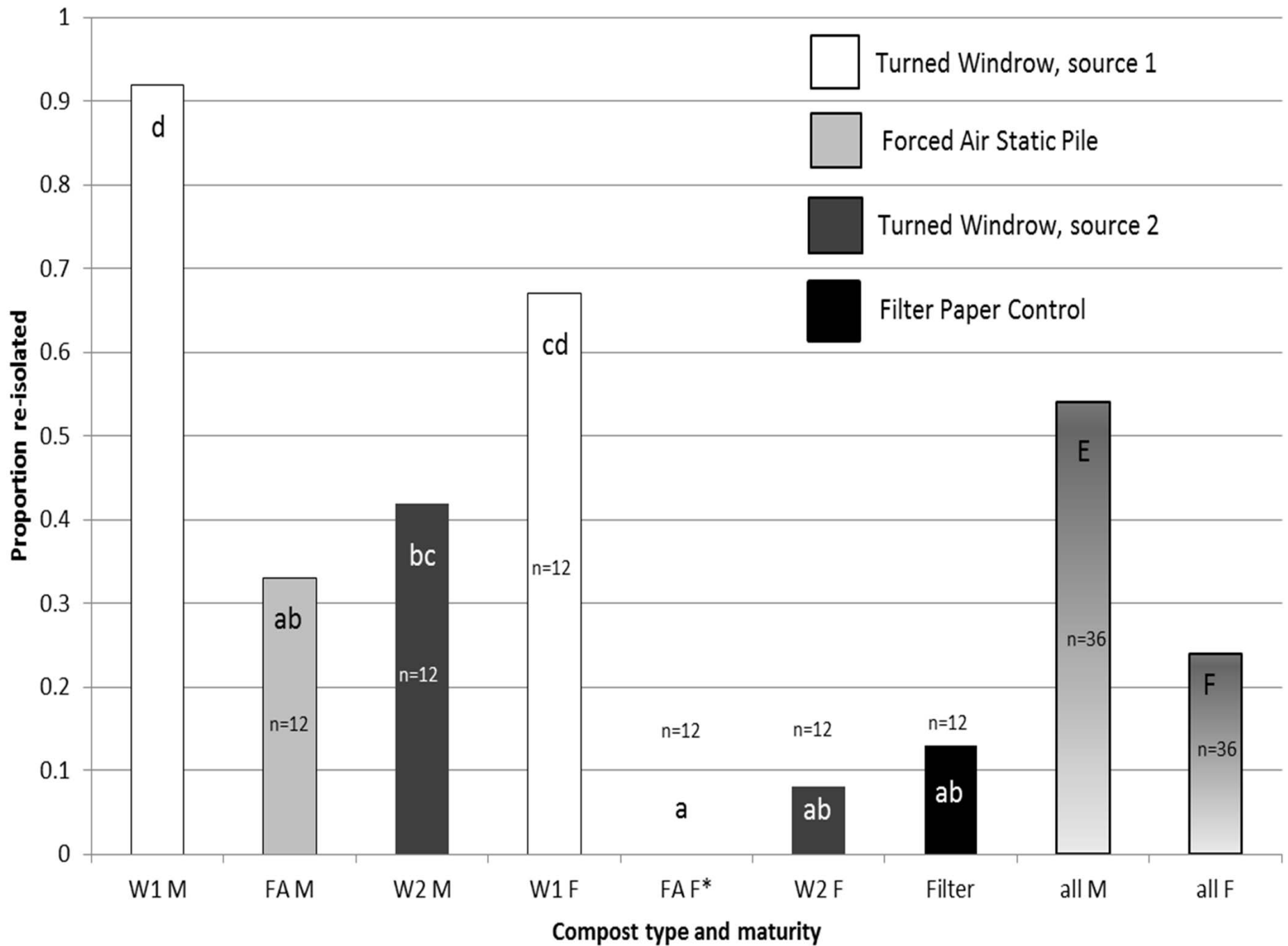
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 - <https://www.youtube.com/watch?v=hsdYrSgR4Ag>
- Zoospores
 - Delicate hunting spores
 - Cysts



Image: Rizzo Lab, UC Davis





Conclusions

- Can it survive if introduced into finished compost?
 - Yes, even zoospores can survive ...
 - if introduced at high enough rates, and held under relatively ideal conditions (cool and moist).
 - Survival is much higher in aged composts than in fresh composts
 - Caveat: This was an “Is it possible?” kind of question, not necessarily “is it likely?”
 - We’d also need to consider the *Phytophthora* species in question if extrapolating

Compost production

- Facilities should be distant from contamination sources
 - Wind blown water
 - Surface flow
 - How far?
 - 3 miles?!
 - 30 feet?
- Tarping?



Compost production

- Loaders used for moving fresh material should be cleaned before moving to finished composts



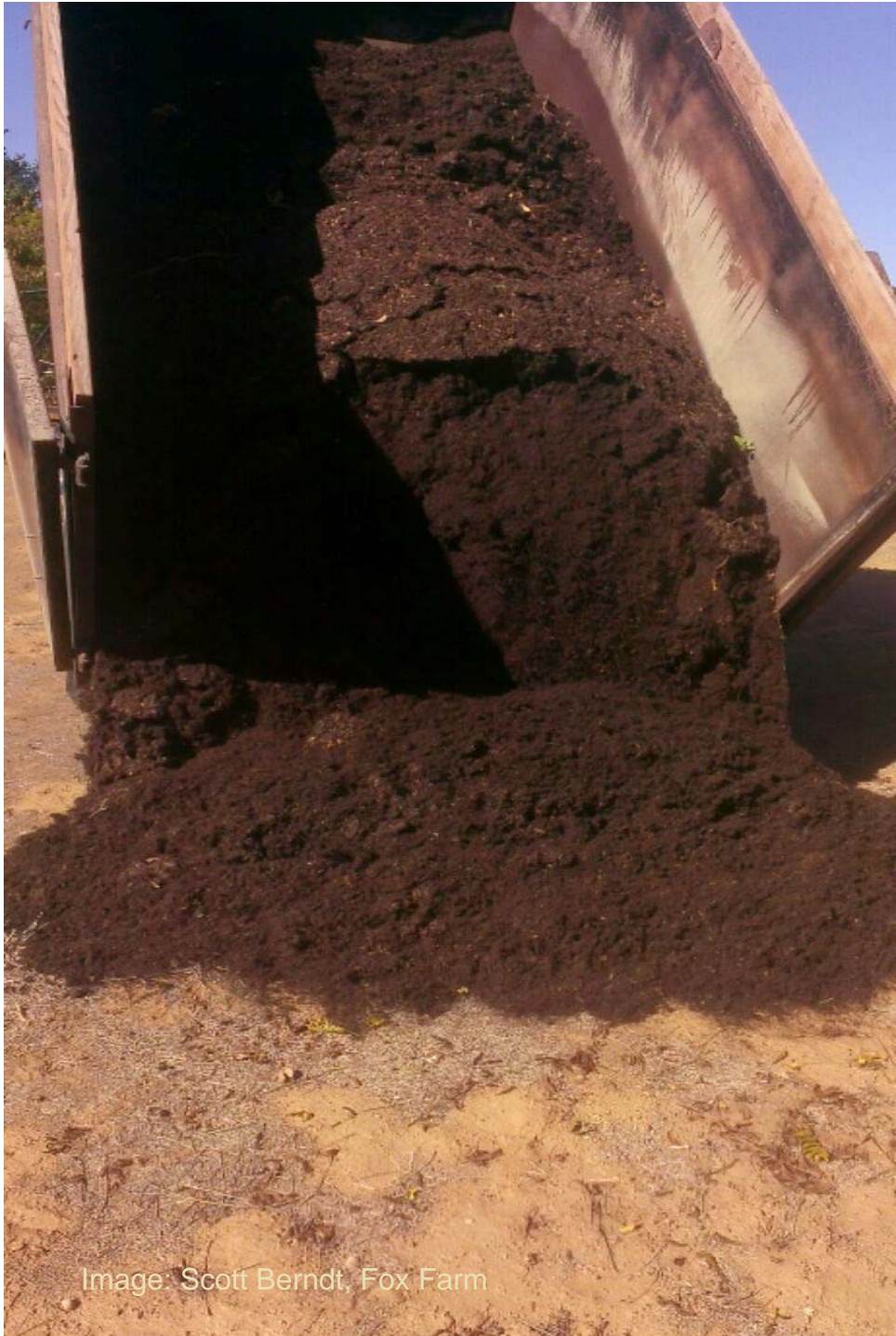


Image: Scott Berndt, Fox Farm

Compost consumption

- Is compost safe?
 - Probably
 - Still hot is good
 - If bagged, is it less likely to be contaminated?
 - It's hard to get aged compost
 - Beneficials can infest it too
 - At your site ...



Image: Urban Forest Collaborative

Mulch consumption

- Is mulch safe?
 - Probably
 - Still hot is good
 - Lava rock and mylar aren't typically good growth media ...
 - Compost on site first?

Thanks!

- www.suddenoakdeath.org
- This presentation is on line at: <http://ucanr.edu/MarinIPM>
- Steven Swain: svswain@ucanr.edu
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- Forced air and windrow composting images: Washington State University website,
<http://organic.tfrec.wsu.edu/compost/ImagesWeb/CompSys.html>
- Other images by Garbelotto or Rizzo labs, UC Berkeley and Davis respectively, except where noted