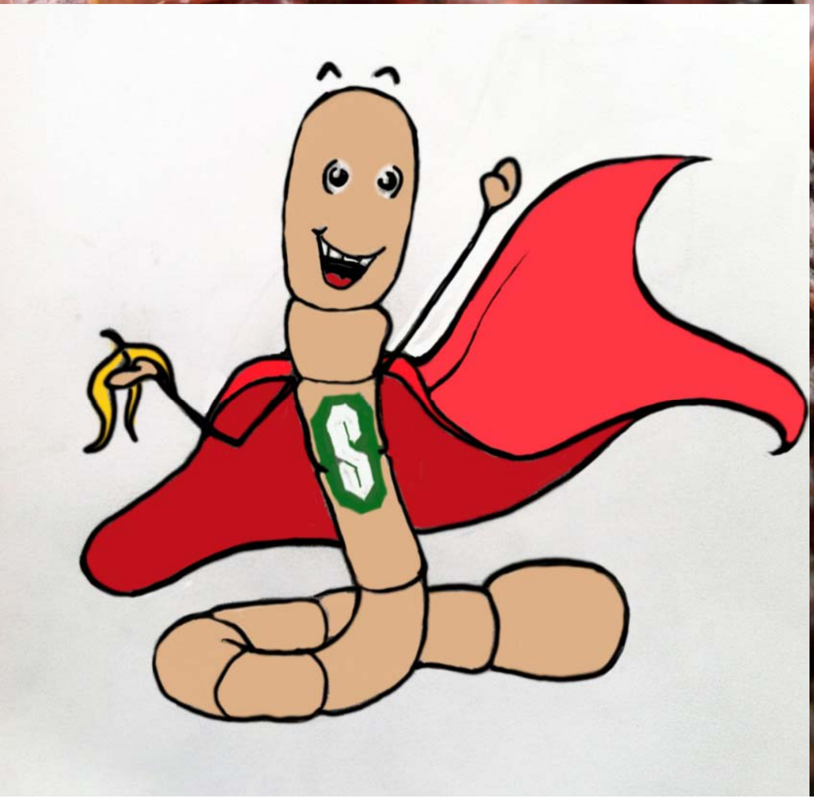

Vermiculture 101: Earthworm Biological, Environmental and Quality Parameters of Importance

Managing Earthworms as Livestock

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Many Aspects of Vermicomposting

- Raising earthworms for bait
- Processing animal manure
- Processing food scraps or organic matter
- Making vermicompost
  - For fertility for crop production
  - For plant health management
  - For compost water extracts / teas

Basics

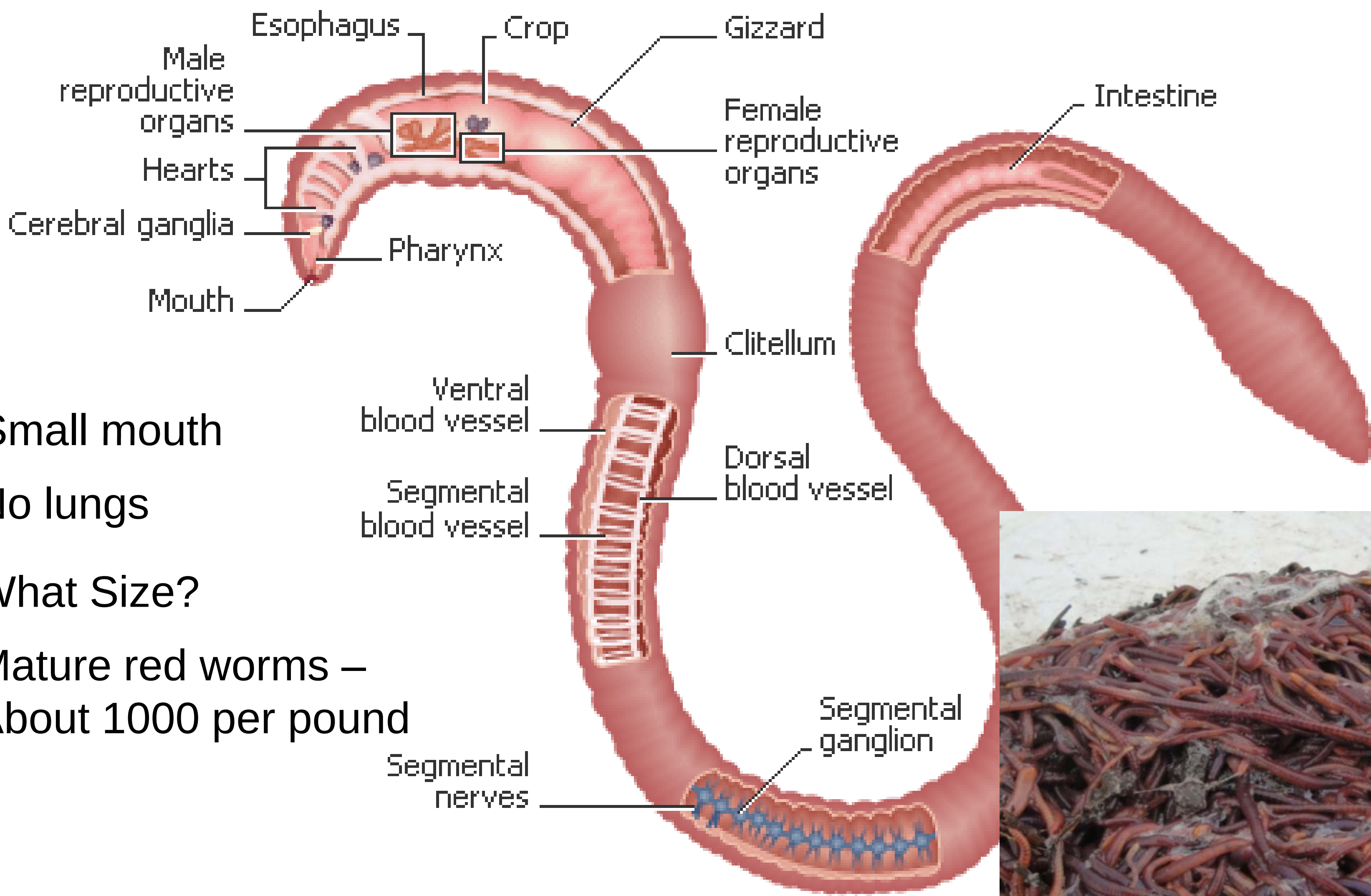
- Production (biology/systems)
- Use (Quality, methods)
- Marketing (rules, regulations, expectations)

- Shared foundation of knowledge (language)
- Start at the beginning

Possible Goals

- Raise and sell healthy worms
- Produce a high quality source of organic matter to amend soils – holds water
- Produce a source of soluble nutrients suitable for organic farming or containerized plant production
- Make a growing medium
- Provide a source of microbiology that can be used to improve plant health and resilience
- Manage worms as livestock

Worm Anatomy



Small mouth

No lungs

What Size?

Mature red worms –
About 1000 per pound

http://www.reaps.org/compost/reproductive-system.html

Earthworms exchanging sperm

http://northeastparkscience.wordpress.com/page/2/

Cocoons

Emerging Earthworm

http://www.vermica.com/articles/worm_birth.htm

How Fast do Earthworms Reproduce?

- Reported time for cocoon to go from formation to hatching in favorable conditions: 4 to 6 weeks
- Reported time that cocoon can provide protect in unfavorable conditions: months to years
- Reported time to develop from emergence to maturity (ability to produce young): 6 to 8 weeks? Or 60-90 days?
- Reported time *E. fetida* will live, feed and reproduce in a favorable environment: 3-4 years
- Reported that a mature *E. fetida* can release up to 2 to 3 cocoons per week
- Reported that in an earthworm bin the population can double about every 2 months.

Environmental and Quality Parameters of Importance

1. Population Density
2. Feed
3. Oxygen
4. Moisture
5. Temperature
6. Light
7. pH
8. Ammonia
9. Soluble Salts (electrical conductivity)
10. Bulk Density
11. Microbial Density and Diversity; Human Health and Safety
12. Compost Maturity

Qualitative or Descriptive Terms

- Optimal
- Acceptable
- Target
- Tolerable
- Unacceptable
- Deadly

Providing numbers or numeric ranges that can be measured and compared moves the discussion or recommendation from “qualitative” to “quantitative”.

1. Population Density

- How to quantify or characterize?
- What is the acceptable range?
- What method is used to take a measurement?
- 1 lb of earthworms/ft^2 of bed surface area as a minimum for rapid composting?
- 2 to 3 lbs/ft^2 as a high population?
- Guidelines for organic certification of vermicompost provides a time requirement but not a requirement for population density.

2. Bedding and Feed – Answers Needed

- What to feed?
- When to feed it?
- How much to feed?
- How to feed?

- How does feed influence the final product?

2. Bedding and Feed: What to feed?

- Components:
  - Carbon, Nitrogen, Minerals
- Carbon – energy
  - Sugar, starch, cellulose, lignin
  - Straw, leaves, shavings, etc.
- Nitrogen – for protein and growth
  - Nitrate, ammonium, amino acids, protein
  - Manure, hay, grains, seeds, coffee, etc.
- Minerals
  - Nitrogen, phosphorus, potassium
  - Calcium, magnesium, sulfur
  - Iron, manganese, copper, zinc, boron, molybdenum, chloride, others

2. Bedding and Feed: Analysis

- Carbon – organic matter - carbon is removed by burning, ash remains
- Nitrogen – carbon is digested away by sulfuric acid and N remains (Kjeldahl method)
- Total Minerals (ash is dissolved in acid)
- Available minerals (minerals are extracted from feedstocks or compost with water)
  - Also called greenhouse test or saturated medium extract (SME); includes pH and soluble salts by electrical conductivity (EC)

2. Bedding and Feed - Minerals

- Intensity – available or dissolved part (measured in parts per million or %)
- Capacity – reserve or not soluble part (measured in cation exchange capacity)
- Balance – ratios between elements
  - Ex: 60-80% Ca, 10-20% Mg, 5-10% K
- Availability – soluble fraction changes with acidic or basic (pH)

2. Feeding Rate (When & How Much?)

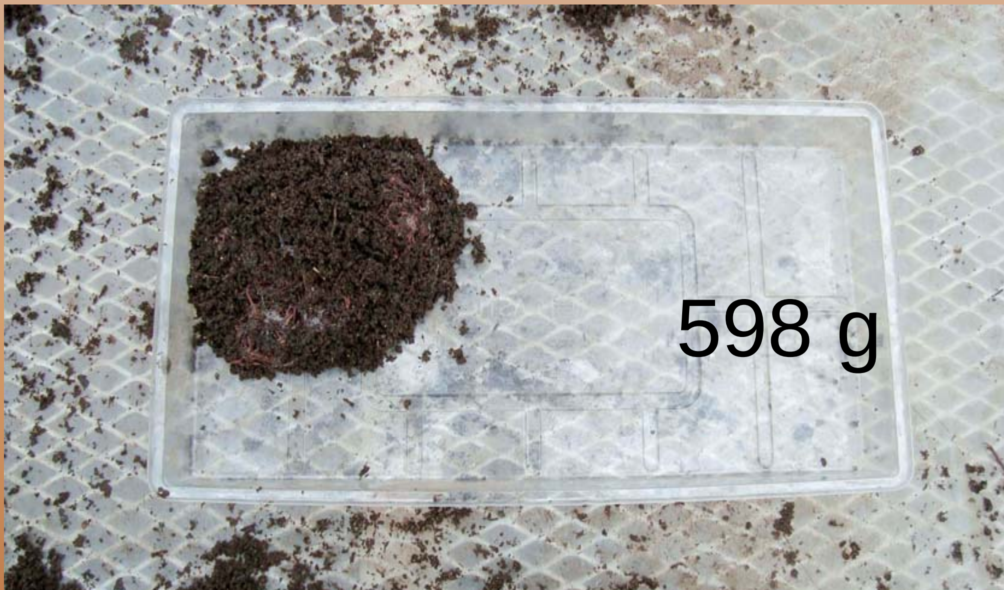
- How to quantify?
  - Percent of worm body weight?
  - Lbs of food per pound of worms?
  - Not just a schedule – based on observation of rate of consumption
  - How does temperature effect feeding?
- Importance of moisture content
  - 100 lbs at 75% moisture is 25 lbs dry food
  - 100 lbs at 50% moisture is 50 lbs dry food
- Importance of particle size: finer = faster
- Effect of precomposting
  - Effects moisture and minerals
  - Is some of the nitrogen lost?

Isolating worms

Feeding Trial

8 weeks later
re-isolate worms

Horse Manure 0.5 body weight/day



Horse Manure 1.0 body weight/day

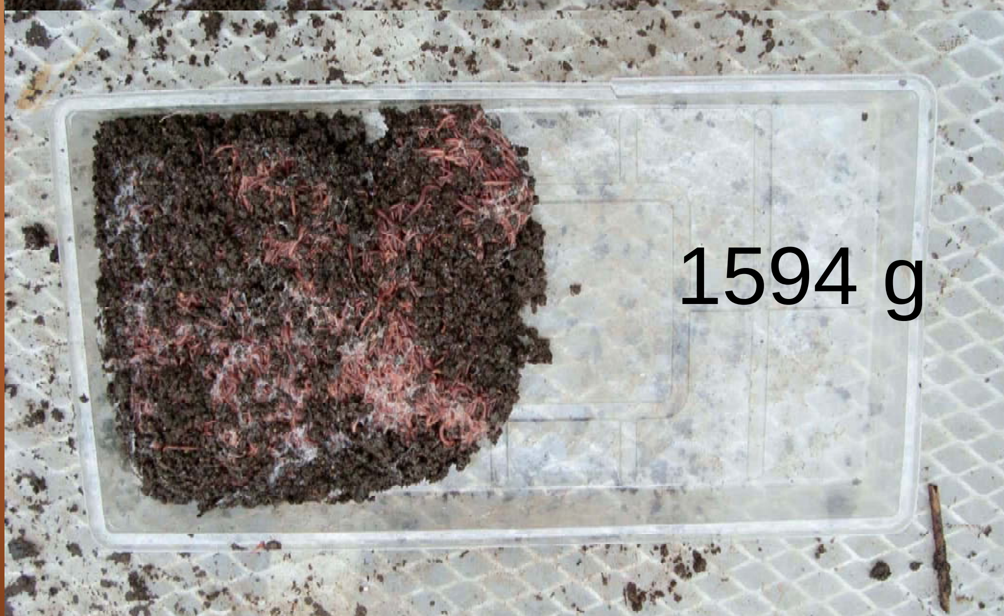
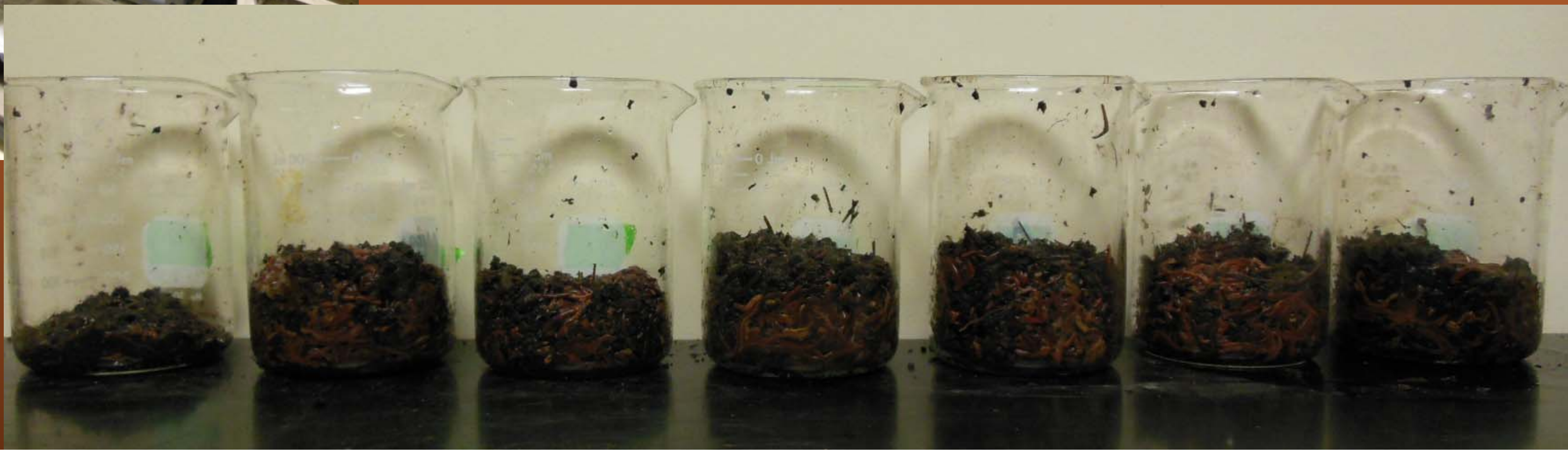


Plate Scrapings Pulper 0.5 body weight/day

Plate Scrapings Pulper 1.0 body weight/day

Starting weight 400 g Nov 13; finish ~600 g (1.5 x) to over 2000 g (5X) Jan 13 or ~ 8 weeks.

Laboratory Feeding Experiment



Laboratory Feeding Experiment

- Leaf mold (aged municipal tree leaves)
- Pineapple rind and leaf mold
- Melon skin / seeds and leaf mold
- Carrot peelings and leaf mold
- Onion peelings and leaf mold (worms did ok)
- Coffee grounds and leaf mold
- Mixture of 5 feedstocks and leaf mold

- Future work: addition of minerals to test effect on the earthworms and the final product.

2. Feeding Strategies

- Bin Method – start with bedding and worms; add food gradually over time at intervals
- Batch Method – add worms to mixture and do not add additional food
- Flow Through and Angled Wedge Method – regular additions of precomposted mixed feed and bedding with worms moving

Bin Method: Fresh Start Mixture

Leaves, Horse Manure, Paper, Compost, Coffee Grounds

3. Oxygen

- Does it become limiting for worms?
- If so, when? Oxygen is more likely to be limiting due to active microorganisms.
- Bacteria can remain active at low oxygen concentration (anaerobic conditions).
- Optimal, tolerable and unacceptable ranges?
- Oxygen solubility in water decreases as water temperature increases.
- Avoid closed containers and high rates of composting activity.

4. Moisture

- A primary management tool
- How measured or calculated?

  % = (Wet weight – dry weight) / wet weight
- Squeeze test for quantifying.
- Optimal, target and tolerable range?

Moisture Content Example

Dry Weight	H_2O Weight	Total	% Moisture	% Change
10	0	10	0	-
10	10	20	50	50
10	20	30	66	16
10	30	40	75	8
10	40	50	80	5
10	50	60	83	3
10	60	70	86	3
10	70	80	87.5	1.5
10	80	90	89	1.5
10	90	100	90	1

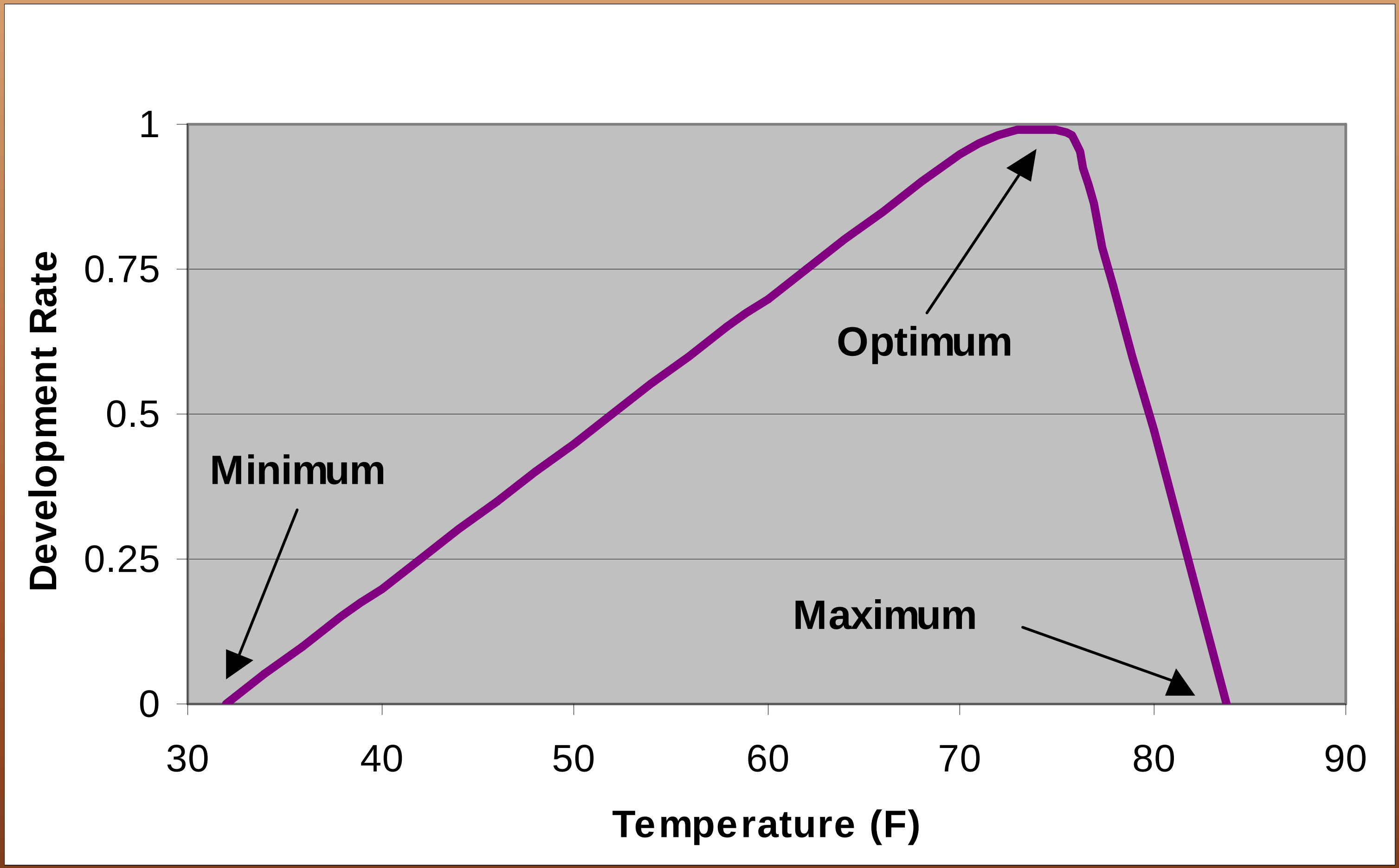
5. Temperature
Fahrenheit and Celsius

Condition	Fahrenheit	Celsius
Freezing	32	0
	50	10
	60	15.5
	70	21.1
	80	26.6
	90	32.1
Boiling	212	100

5. Temperature

- Temperature response curve
- Optimal range: 65 to 75ºF
- Target range: 60 to 80ºF
- Tolerable range: 50 to 90ºF
- Deadly range
- Effect on Oxygen

Graphical Description of the Effect of Temperature on the Rate of Plant Development



Kitchen produce prep is added to the surface and covered with either horse manure (3 beds) or precomposted pulped postconsumer food residue (3 beds). The bed temperature dropped to under 40^{o}F but worms seemed “active”.

Worms were 3 to 4 inches below the surface on a cold day.

E. Fetida in moist bedding with ice crystals

Hoophouse Worms that Survived Winter in a High Tunnel: Container on the Ground

High Tunnel Worms that did not Survive

Off the Ground, Near Outside Wall, Not Tented – Spring Thaw Slime

6. Light

- Intensity measured in foot candles
- Avoid earthworm exposure to bright light – be aware when harvesting
- Low intensity light can be used to keep earthworms from going on a “walk about”
- Does photoperiod – day length matter?

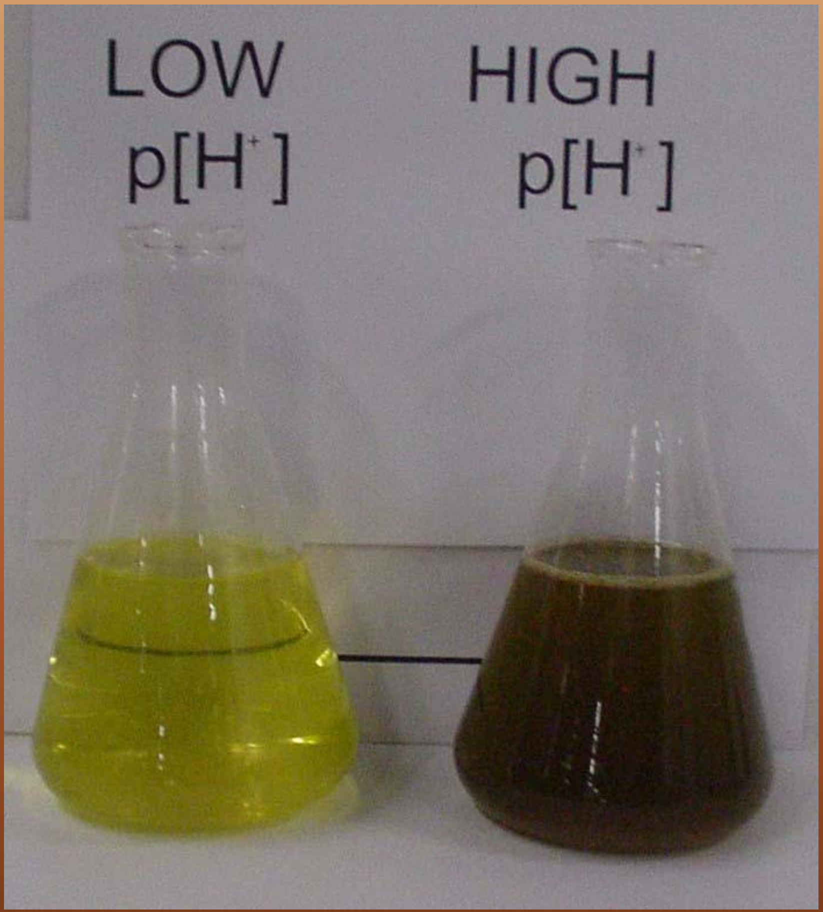
7. Bedding pH

- What is pH?
- How to measure?
- Acceptable range?
- How or when does it change?

Availability – Acidic or Basic - pH

Iron Sulfate

Dissolved **Not Dissolved**



Fe^{++} **$Fe(OH)_2$**

Availability

(pH)

$$H_2O \rightleftharpoons H^+ + OH^-$$

All nutrients are dissolved in water.

8. Ammonia Gas

- A form of nitrogen gas that is toxic to worms at low concentrations
- Ammonium (NH_4^+) is in solution and used by plants and microorganisms; Ammonia (NH_3^+) gas forms if the pH is high, usually above 8.0
- Can be smelled or detected by human nose at about 5 ppm; reported to be toxic to earthworms at 0.5 ppm.
- Usually from active compost or manure
- Managed by keeping pH below 8, preferably <7.5
- Will dissipate if worms and bedding not in a closed container
- A reason not to use plastic film to cover a worm bed to conserve moisture

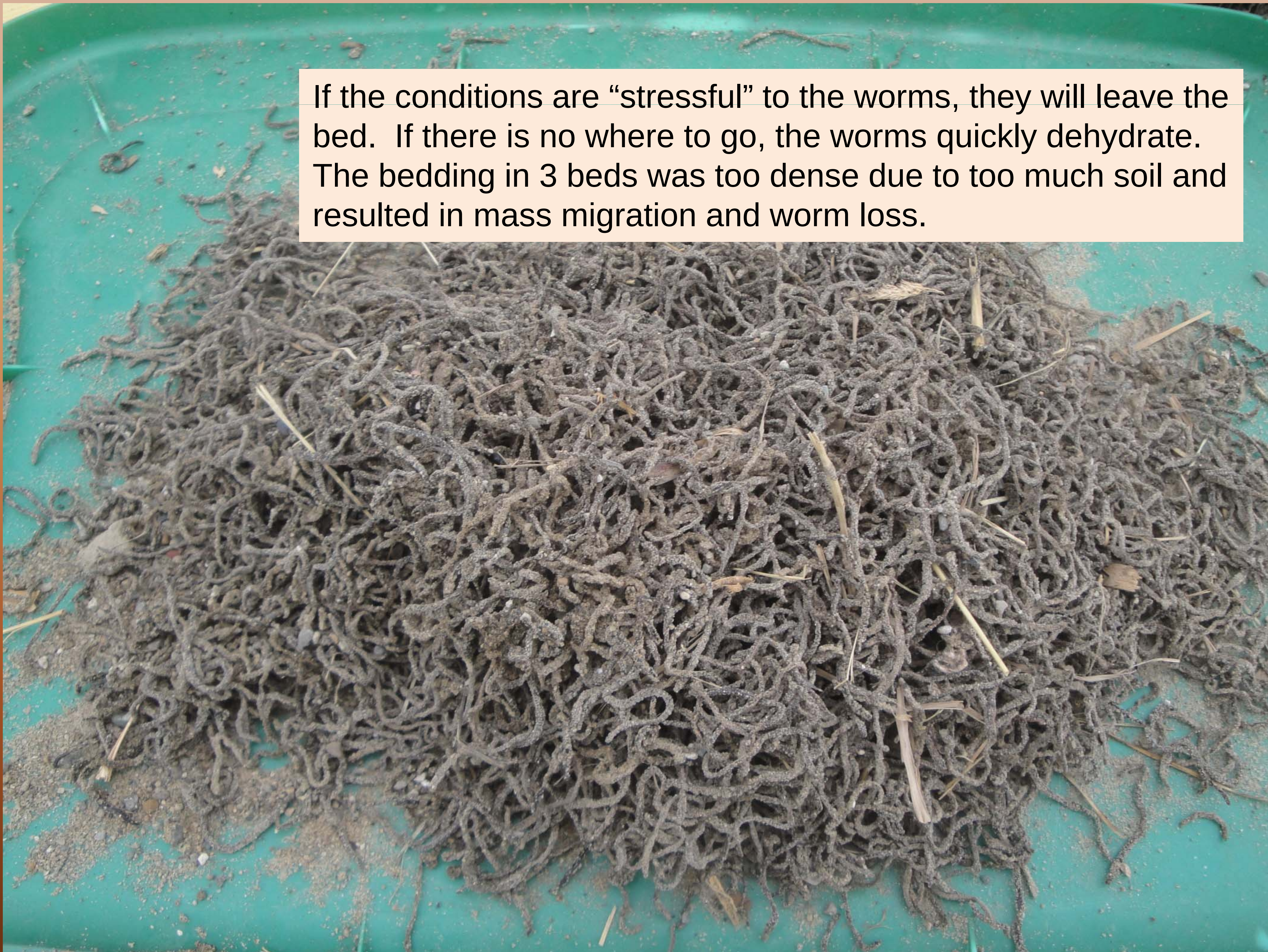
9. Soluble Salts

- Salts are mixed Cations (+) and Anions (-)
- Electrical conductivity (EC)
- How to measure?
- Pure water has zero EC.
- More dissolved salts, higher conductivity.
- Impacts moisture availability

10. Bulk Density (BD)

- Weight per unit volume
  - pounds per cubic yard, grams/cubic centimeter
- Impacts Oxygen transfer and Moisture
- Heavier BD is an indicator of decomposition.
- Range of values provided in handout.
- Heavier indicates soil present. Ok for worms and use on farm, but most buying customers do not want to pay for soil or sand in vermicompost.

If the conditions are “stressful” to the worms, they will leave the bed. If there is no where to go, the worms quickly dehydrate. The bedding in 3 beds was too dense due to too much soil and resulted in mass migration and worm loss.



11. Microbial Density and Diversity

- Density: Soil or compost respiration – the rate of carbon dioxide release
  - Solvita test kit from Woods End Laboratory
- Microbial diversity – microscope or lab test
  - Bacteria, fungi, nematodes, others
  - Reportedly as many as 5,000 to 10,000 types in as little as a gram of soil
  - High compost temperature can reduce diversity of organisms
- Hot compost vs vermicompost: Diversity
- Human pathogen reduction – food safety

12. Compost Maturity

- Definitions of compost stability and maturity – reduced CO_2 loss, increased nitrates, falling pH and ammonium
- Can vermicompost be used right at the point of harvest?
  - Used for what? Gardening? Addition to mature plants? Starting seeds or transplant medium?

Environmental Parameter Summary

(Based on literature and experience, not experimental measurement)

Parameter	Tolerable	Acceptable	Target
Population Density	? lbs/ft^2	0.5 to 3 lbs/ft^2 ?	1 to 2 lbs/ft^2
Food (lbs/lb/day)	?	0.2 to 1.0	0.3 to 0.5
Oxygen (%)	? %	? %	> 15 %
Moisture (% wet)	50 to 95 % ?	60 to 90 %	70 to 80 %
Moisture Storage	30 to 50% ?		
Temperature (^oF)	40 to 90	60 to 80	65-75
Light (footcandles)	< 1000?	?	dark
Bedding pH	4 to 9	5.5 to 8	6 to 7
Ammonia (ppm)	< 0.5 ppm	less?	none?
Soluble Salts (mS)	< 8 ms (SME	< 6 mS (SME)	< 4.0 ms (SME)
Bulk Density (Dry)	8-16 lbs/5gal	?	?
Minerals (% - ppm)	?	?	Balanced
Microbiology	?	?	High/Active

Summary and Questions

- Knowledge to increase odds of success.
- Quantifying to help take the guess work out of vermicomposting.
- Compost and vermicompost can vary dramatically in mineral and microbial content and it helps to know what you have.
- Make vermicomposting a serious farming business that manages livestock.
- What else needs to be managed?

Additional Information regarding vermicompost systems and use in separate presentations

Grow Green!

First soil seeds and roots

then leaves flowers and fruit.

Food, friends, freedom and fun

from earth, air, water and sun.

John Biernbaum

(Crawl, Walk, Jog, Run – learn progressively)