



UNDERSTANDING AND USING BIOCHAR PRACTICE GUIDELINES DEVELOPED BY THE UMPQUA BIOCHAR EDUCATION TEAM (UBET)

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Wilson Biochar Associates

Part II: Biochar Applications



AGENDA

1. General Guidelines for Biochar Use in Soil
2. Compost Experiments
3. Barn Protocols
4. Compost Testing
5. Bio-assays



Biochar Decision Support Tool

Biochar Research at USDA-ARS Forage Seed and Cereal Unit

Kristin Trippe, Research Microbiologist
The biochar lab: Claire Phillips, Kylie Meyer, Viola Manning,
Manuel Jaramillo



Northwest Climate Hub
U.S. DEPARTMENT OF AGRICULTURE



WWW.PNWBIOCHAR.ORG

Learn about your soil properties



Learn about your crop requirements



What is biochar?

Learn how charcoal-rich soils in the Amazon have influenced soil management world-wide.



What are the benefits of biochar?

Learn how biochar can benefit agriculture, natural ecosystems, and rural livelihoods.



How are people making and using biochar?

See applications in horticulture, farming, forestry, and environmental remediation.



Will biochar do what I want?

Learn how feedstocks, production conditions, and additives determine how biochar interacts with your soil.

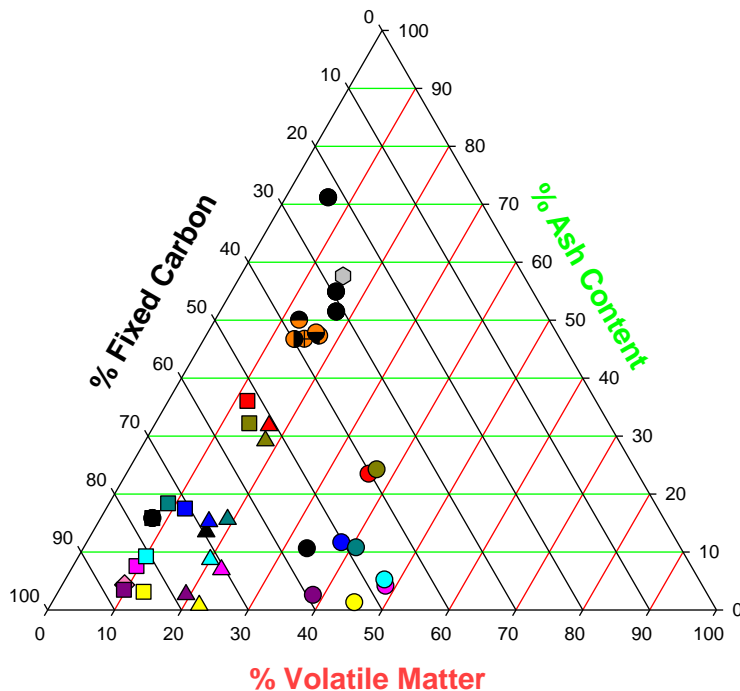


Where can I get biochar?

A range of biochars are increasingly available for sale.

BIOCHAR: feedstock origin and production conditions impacts physiochemical properties

**Ternary Plot of Proximate Carbon Fractions
Formosa Mine Extract Study - Summer 2014**



- Arundo donax - 300 C°
- ▲ Arundo donax - 500 C°
- Arundo donax - 700 C°
- Anaerobically Digested Fiber - 300 C°
- ▲ Anaerobically Digested Fiber - 500 C°
- Anaerobically Digested Fiber - 700 C°
- ARS Char #1
- ARS Char #2
- ARS Char #3
- ARS Char #4
- ARS Char #5
- ARS Kentucky Bluegrass Seed Screenings
- ARS Rice Seed Screenings
- ARS Tall Fescue Seed Screenings
- ARS Wood
- Douglas fir - 300 C°
- ▲ Douglas fir - 500 C°
- Douglas fir - 700 C°
- ◇ Dairy Manure Biochar (Enchar)
- Elymus - 300 C°
- ▲ Elymus - 500 C°
- Elymus - 700 C°
- ◇ Granulated Activated Charcoal
- Hazelnut Shells - 300 C°
- ▲ Hazelnut Shells - 500 C°
- Hazelnut Shells - 700 C°
- Miscanthus - 300 C°
- ▲ Miscanthus - 500 C°
- Miscanthus - 700 C°
- Oregon White Oak - 300 C°
- ▲ Oregon White Oak - 500 C°
- Oregon White Oak - 700 C°
- Spent Brewer's Grain - 300 C°
- ▲ Spent Brewer's Grain - 500 C°
- Spent Brewer's Grain - 700 C°
- Sorghum - 300 C°
- ▲ Sorghum - 500 C°
- Sorghum - 700 C°



The IBI Classification System

Carbon Storage Class	1	$sBC_{+100} = 98.7g\ kg^{-1}$
Fertilizer Class	4	$P_{2t}\ K_{2t}\ S_{5t}\ Mg_{3t}$
Liming Class	2	$CaCO_3 - eq = 13.0\%$
Particle Size Class	Pd	Blended Powder

<https://www.biochar-international.org/biochar-classification-tool/>



Camps Arbostain M, J.E. Amonette, B. Singh, T. Wang, H-P. Schmidt. 2015. *A Biochar Classification System and Associated Test Methods*. In: [Biochar for Environmental Management – Science and Technology, 2nd edition](#). J. Lehmann and S. Joseph (eds.). Routledge.

General Guidelines

- Flame carbonization produces mostly high temperature biochar (between 500 – 1000 C), but it is not consistent
- High temperature biochar has proportionally more C and ash, less volatile matter and higher pH
- Low temperature biochar with lots of volatile matter can cause nutrient tie-up by providing lots of labile carbon, causing a microbial “bloom”
- Biochar properties do not have to be consistent to work well in soil, especially if composted first
- Always check biochar pH. Use caution when adding to high pH soil. Composting and fermentation are effective in lowering biochar pH



Biochar and Soil pH

- Low T biochar is close to neutral (less ash and more organic acids)
- High T biochar is alkaline (around pH 8-10)
- Great for acid soils
- Alkaline biochar can be neutralized several ways:
 1. Rinse away ash with water
 2. Compost with organics – sorbs organic acids – creates organic coating
 3. Add an acidifier like wood vinegar, acetic acid, citric acid, sulfur

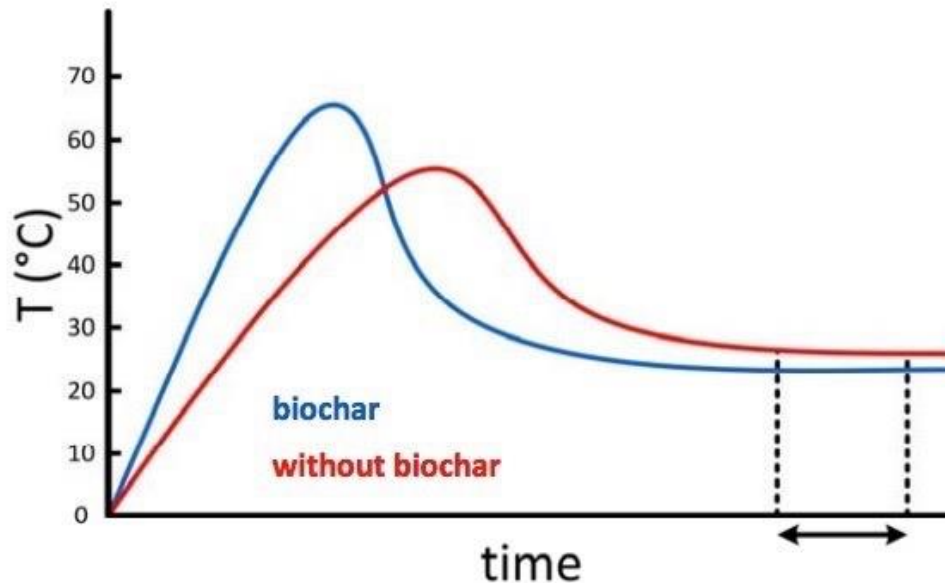


Composting and Biochar

- Composting “charges” biochar with nutrients and life
- Biochar improves composting process by retaining air and water
- Composting adds organic acids that reduce biochar pH
- Composting allows microbes to digest volatile matter in low temperature biochar
- Mature compost with biochar is ready to add to soil



Possible Benefit of Biochar to Compost



Biochar increases the temperature in a compost process, accelerating the time needed for material decomposition^{4, 6, 7}

- Only occurs if you have C:N right
- Also depends on C:N impact of biochar



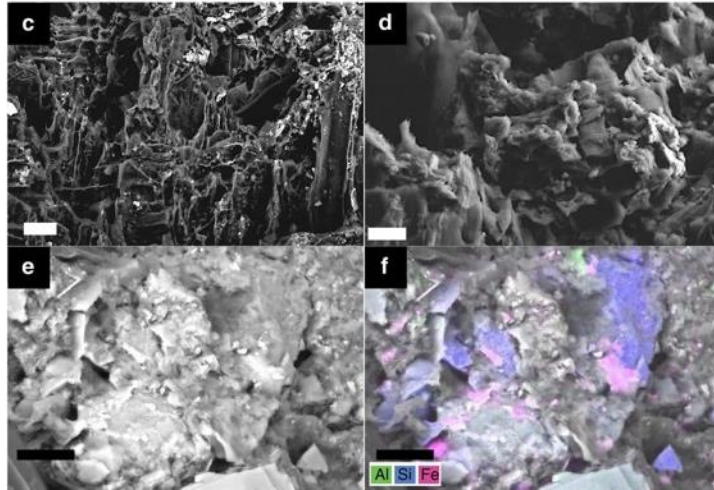
What is the C:N of biochar?

- Typically, only about 10-30% of the total C in biochar is mobile and available*
- C:N of biochar itself could be about 100:1 or greater – it depends on the biochar
- **IMPORTANT:** Biochar influences C:N by absorbing N
- **Possibly IMPORTANT:** Biochar influences C:N by absorbing labile or active C
- Biochar content for good manure compost ranges from 5%-50% depending on C:N of manure + bedding



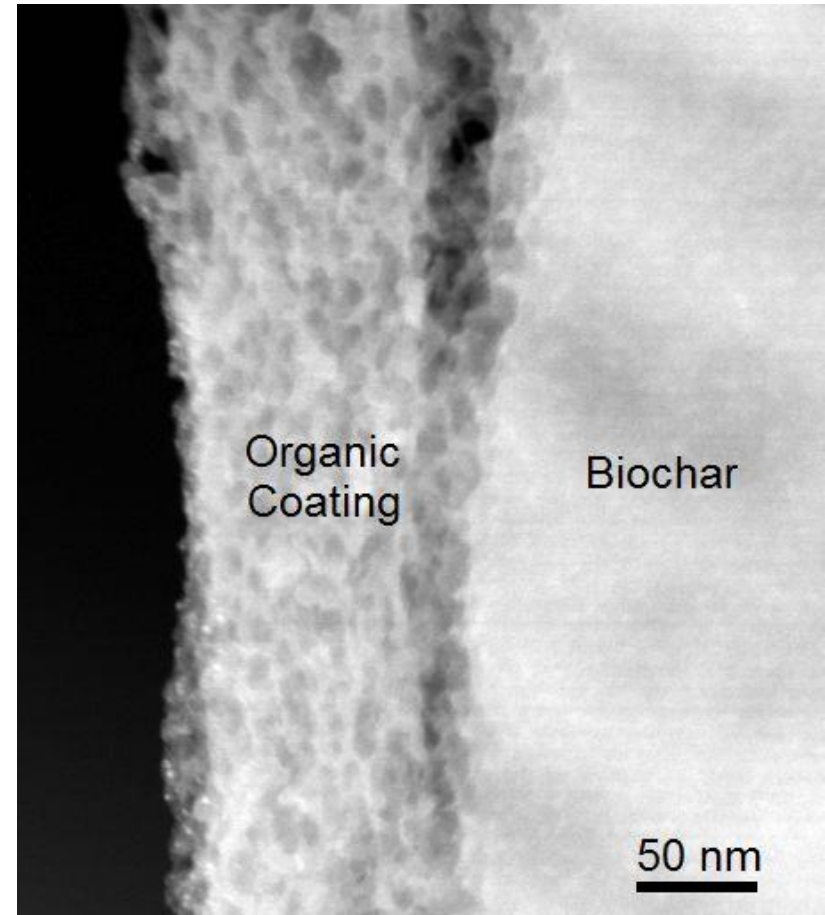
[*http://www.terra-char.com/uploads/2/3/7/9/23790961/composting_with_biochar.pdf](http://www.terra-char.com/uploads/2/3/7/9/23790961/composting_with_biochar.pdf)

Organic coating on biochar surfaces



Hagemann, Nikolas, et al. "Organic coating on biochar explains its nutrient retention and stimulation of soil fertility." *Nature communications* 8.1 (2017): 1089.

Composting biochar with other organic material produces an organic coating on biochar surfaces.



What is in that organic coating?

Cations

- Ammonium
- Calcium
- Magnesium

Organic compounds

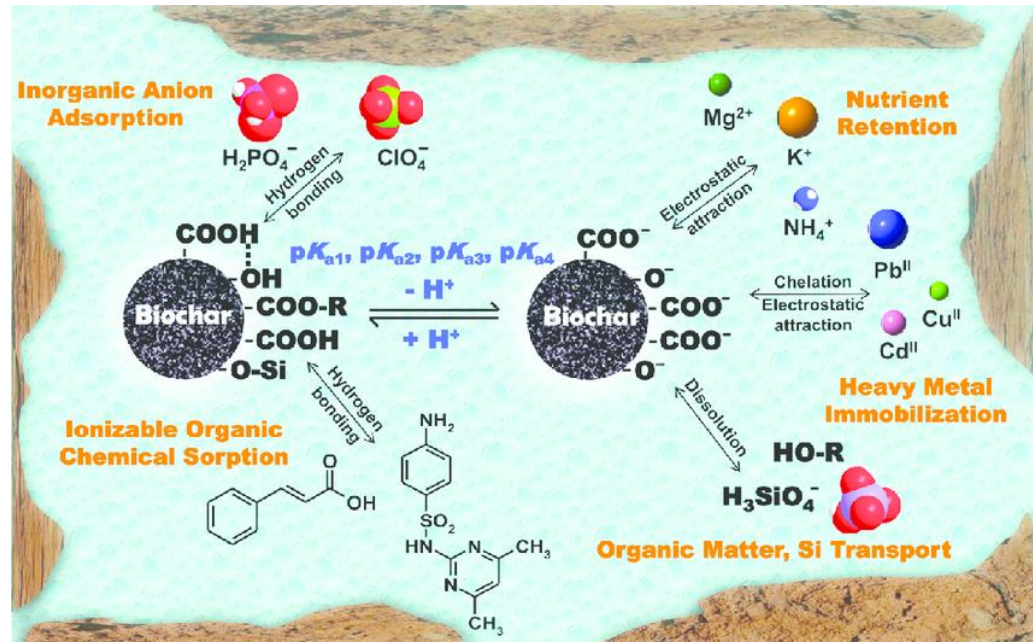
- Organic functional groups
- Humic acid

Anions

- Phosphate
- Nitrate
- Sulfate

Minerals

- Metals
- Clay



Schematic of the pH-dependent dissociation of acid/base groups on the biochar surface and the environmental implications.

Chen, Zaiming, et al. "Quantification of chemical states, dissociation constants and contents of oxygen-containing groups on the surface of biochars produced at different temperatures." *Environmental science & technology* 49.1 (2014): 309-317.



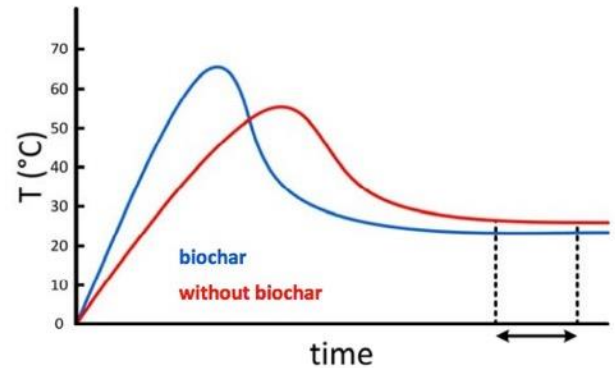
Don Morrison's Successful Compost Pile



2 parts biochar; 2 parts fresh, hot, smelly dairy manure; 3 parts goat barn waste. Pile was hot for weeks. Never turned. Lots of worms at the end.



Biochar + Manure = Fast, Hot Compost



Biochar increases the temperature in a compost process, accelerating the time needed for material decomposition^{4, 6, 7}



Composted Biochar Performs

We picked char particles out of the compost and tested them in soil mixes



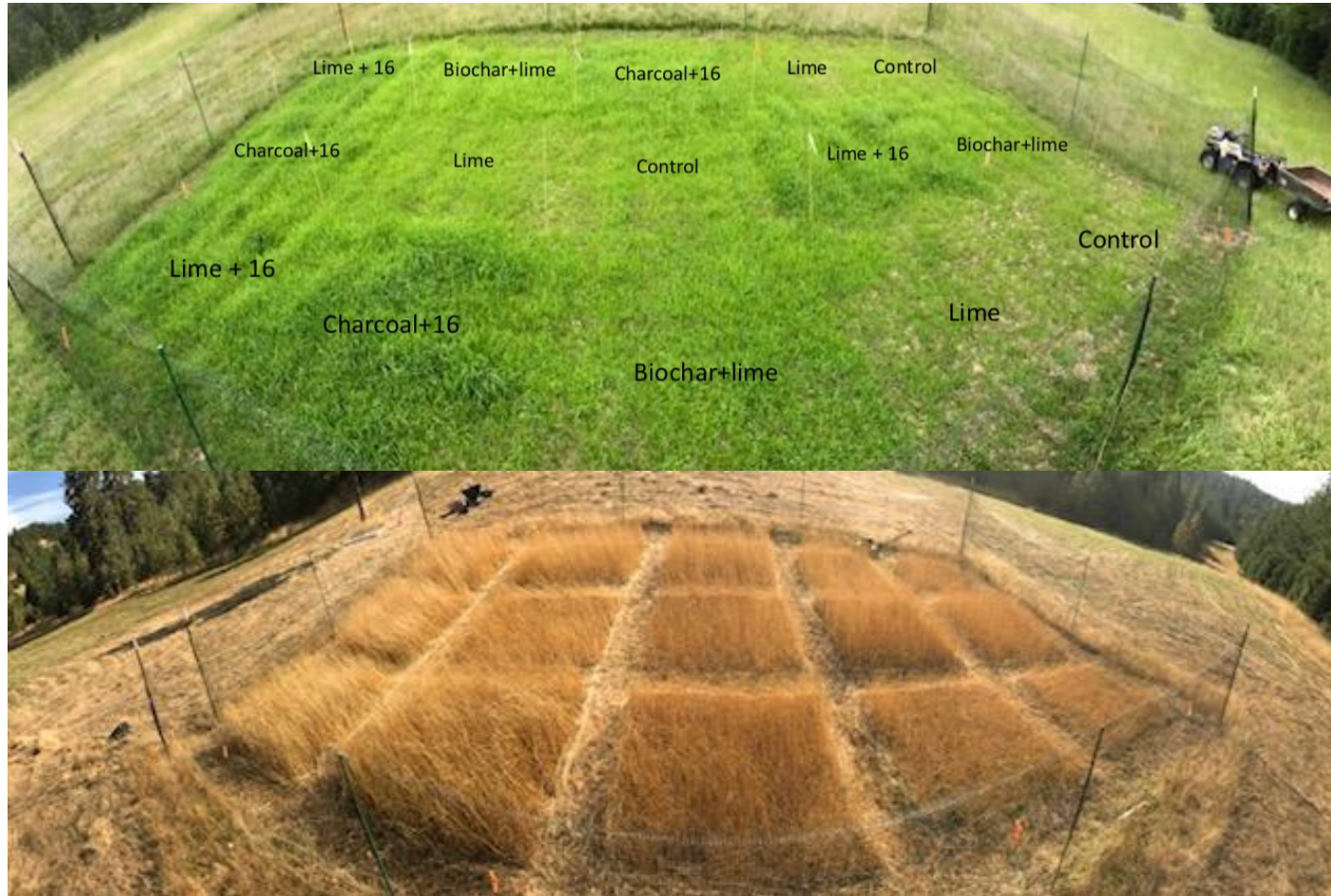
From L to R: composted biochar, worm castings, control

Treatment	Germination (%)	Secondary Leaves (count)	Biomass (grams)
Composted char	100	67	2.04
Worm Castings	84	57	1.87
Control	98	41	1.30



Organic coatings on biochar surfaces had an impact!

Don Morrison's Hay Field Trial

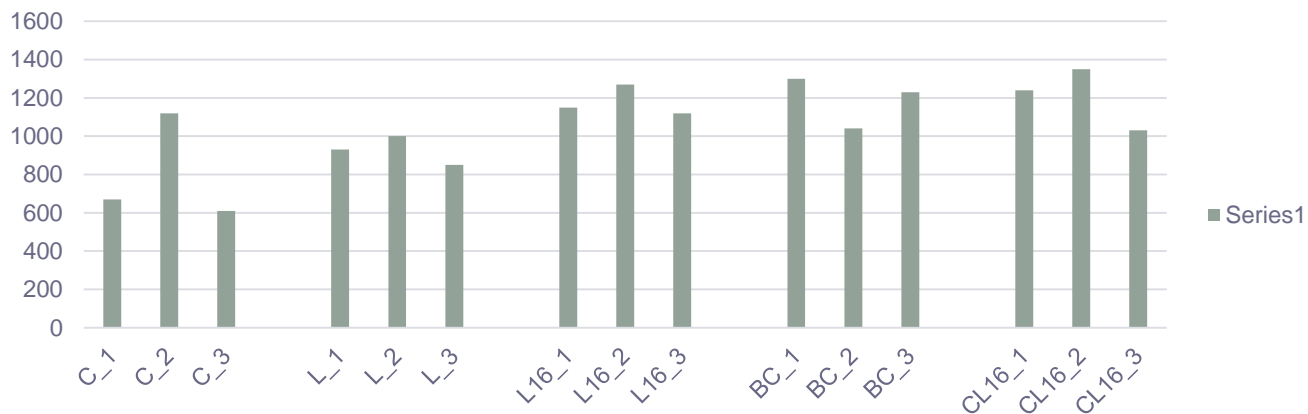


Field trial with 3 replicates in 3 blocks

Biochar compost equal to NPK fertilizer



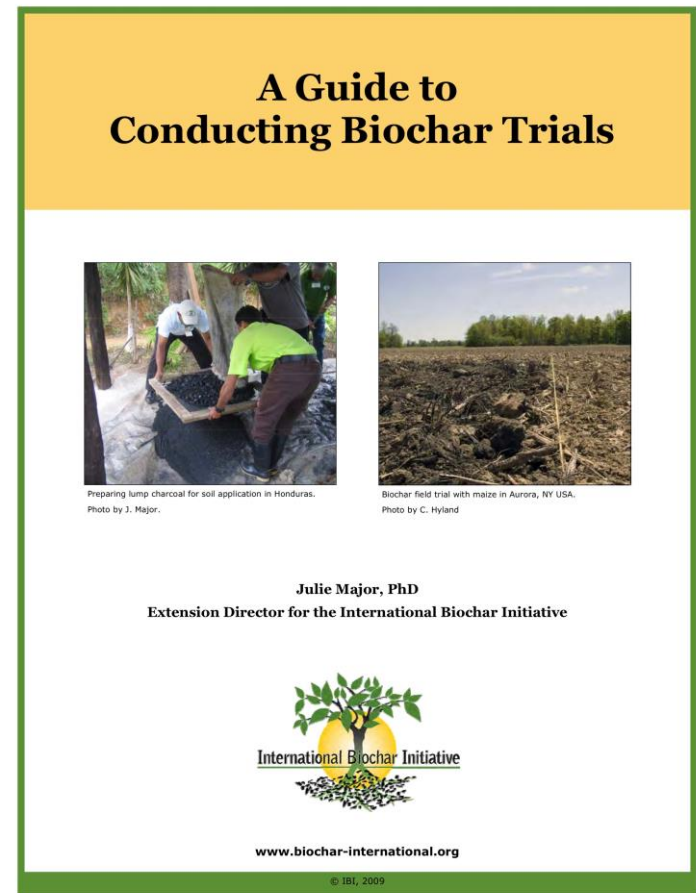
Treatment harvest weight (grams)



Composted biochar, biochar + triple 16, and lime + triple 16 all did equally well

Biochar Field Trials - Tips

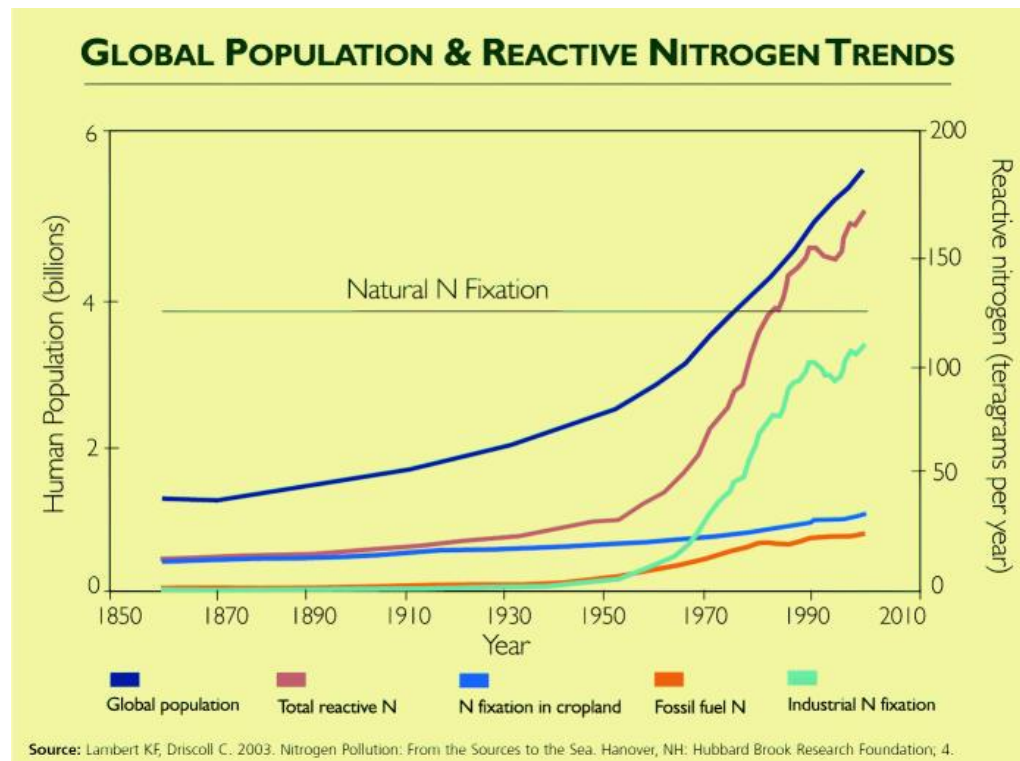
- Keep it simple
- Keep plot sizes small (10' x 10')
- Use complete randomized block design
- Great reference on IBI website



https://www.biochar-international.org/wp-content/uploads/2018/04/IBI_Biochar_Trial_Guide_final.pdf

Manure Management with Biochar: Use C to Manage N

- Although carbon dioxide may get more press, “the nitrogen cycle has been altered more than any other basic element cycle.”*



*John Aber, vice president for research and public service at the University of New Hampshire.

Michaels Ranch - Days Creek, Oregon



- Grass-fed beef and lamb
- 200 beef cow/calf pairs, 200 yearlings and 325 ewes
- 450 acres of grazing land
- Feed barn used only in winter when pastures are wet



Michaels Ranch Compost 2016



Observations from 2016 compost:

- Biochar added after barn cleaning
- Biochar poorly mixed
- Clumpy texture difficult to spread on field
- Never got hotter than 90 degrees
- Plain manure pile did not heat either



Michaels Ranch Compost 2017

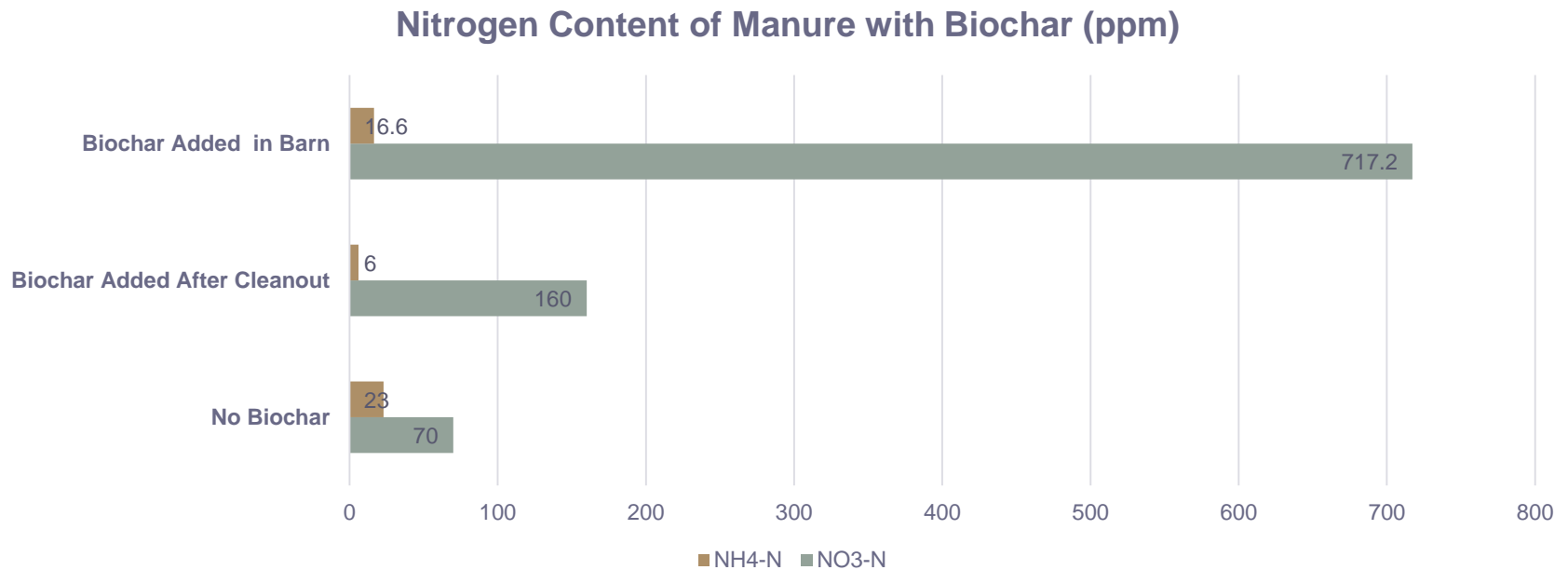


Observations of 2017 Compost:

- Biochar added early so cows could mix it
- Pile got hot – at least 130 degrees
- Fine, friable texture—easier to spread on field



For best results, mix biochar with manure as it is generated



Biochar added in barn absorbed more N than biochar added after cleanout



Pack Barn Composting with EM-1

- In Germany, sauerkraut juice is sprayed in cattle barns to control ammonia odor and kill pathogens
- EM-1 is similar. It includes lactic acid bacteria, yeasts, photosynthetic bacteria with >30 species
- EM-1 bacteria thrive and outcompete pathogens
- Acidity prevents ammonia volatilization
- One liter of EM-1 costs about \$25
- You can brew 5 gallons of EM-1 using the one liter starter culture
- You dilute the strong brew 20:1 with water and some molasses before application



EM-1 Brew



http://www.harmonyorganics.net/EM1_APPLICATION_MANUAL.pdf

Willow Witt Ranch Goat Dairy



- Once a week, two 5 gallon buckets of biochar are spread on top of bedding in the wettest part of the barn
- Wet area is approximately 12'x20'
- 1 to 2 liters of diluted EM-1 is sprayed on top of biochar
- At biochar price of \$125/cy, it costs \$6.25 a week to eliminate ammonia smells



Willow Witt Ranch – Results



“We were very impressed by the odor reducing power of biochar. It sure has improved our barns. When you dig into the floor, it looks like it’s composting really well. Instead of the plate of waste hay and alfalfa and pee and poop, it’s nice compost.”

- Suzanne Willow



Siskiyou Alpaca

- Herd of 70 alpacas
- PacaPoo compost is a revenue source
- Poo piles are removed from barn daily and stacked in covered windrows



Compost Experiment Observations:

Pacapoo **without** biochar

- Got several degrees **hotter**
- Had more worms at the end
- Appeared less mature - no grass on top, slimy manure texture

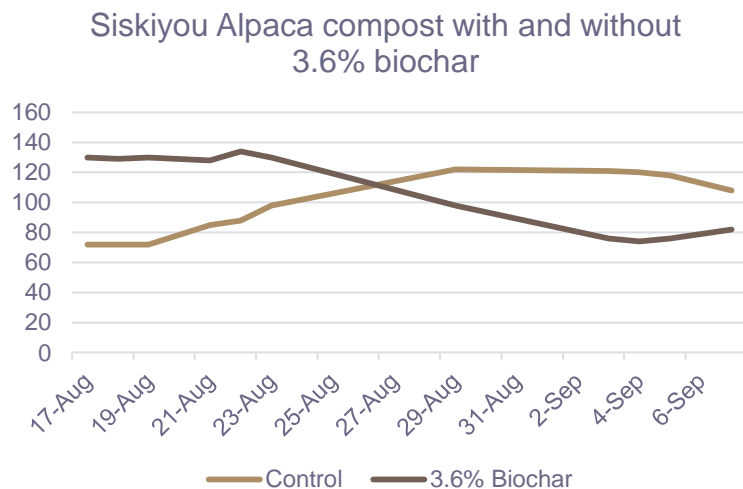
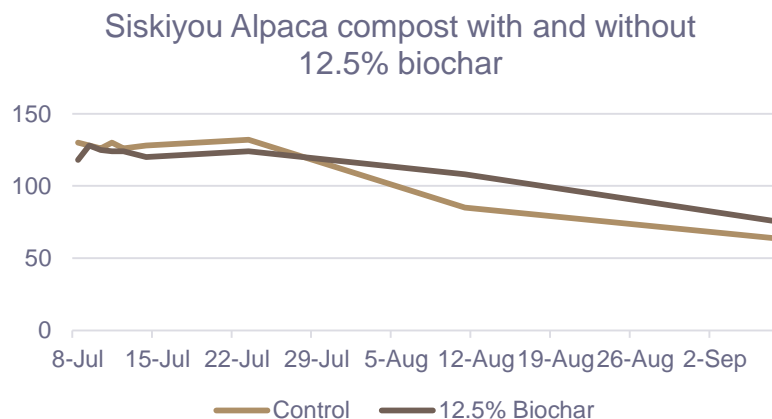
Pacapoo **with** biochar

- Several degrees **cooler**
- Fewer worms
- More mature – grass and weeds growing
- Crumbly, soil-like texture

WHY???



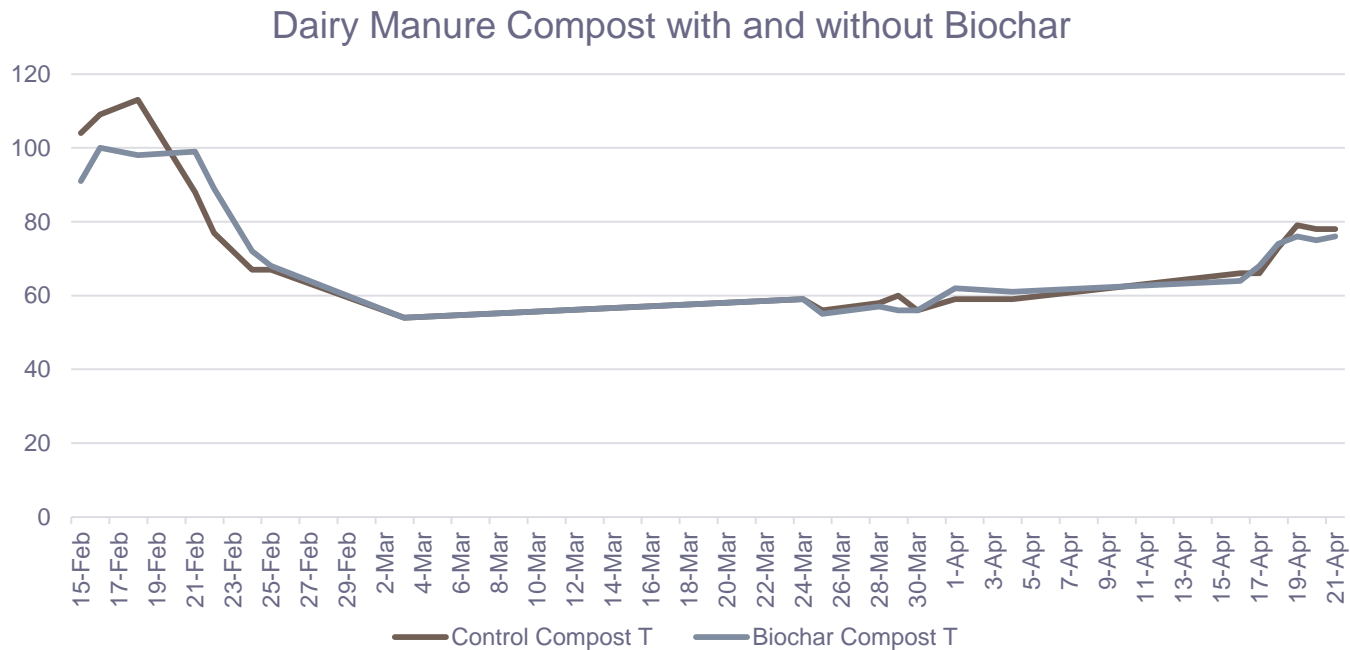
PacaPoo Compost



- 12.5% biochar pile was a few degrees cooler than the control in the beginning, although both piles reached thermophilic temperatures (128F and 130F).
- Opposite trend was observed for the 3.6% biochar pile and its control. Not only did the 3.6% pile get hotter (134F vs 122F), it also reached peak temperature a week earlier.



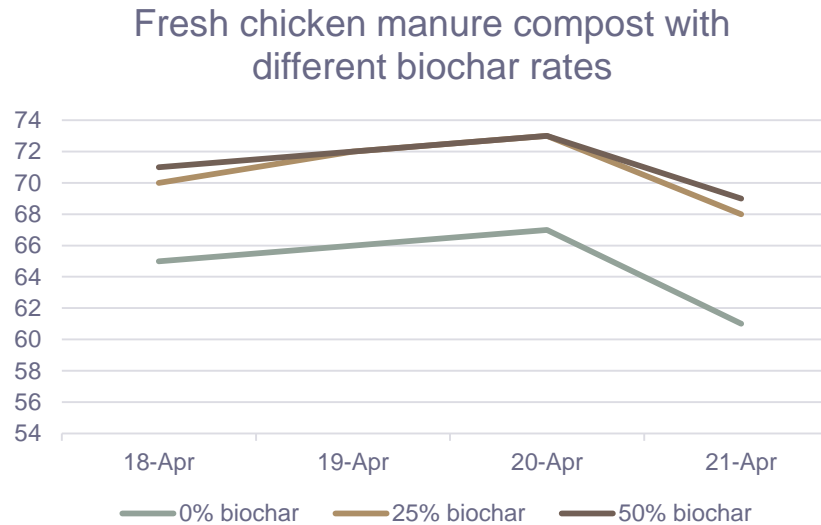
Washed Dairy Manure Experiment



- Dairy manure pile without biochar got hotter
- Dairy manure has high C:N ratio
- C:N of washed dairy manure is about 30:1



Chicken Manure Experiment



Very fresh chicken manure with no bedding composted well with up to 50% biochar

- 50% biochar pile got hotter than 25% biochar pile
- Final pH of 50% pile was **lower** than pH of 25 % pile
- Organic acids deposited by microbial action



NOTE: chickens are not ruminants and their manure has much lower C:N
Laying hen manure is about 6:1 C:N

Setting up a compost experiment



- Use bins, bags, windrows or piles
- You won't need to turn the compost if it has biochar



Compost experiments to test ingredients



Compost mixes in $\frac{1}{2}$ cubic yard fiber bags get hot enough to show differences between recipes



Treatments

- Set up one compost with biochar and one compost without biochar (a control treatment).
- If you like, you can replicate the experiment with multiple piles of each treatment
- Pulverize biochar to a size that is mostly $\frac{1}{4}$ " or smaller. Some larger pieces are ok and will help with aeration.
- Apply biochar at between 3% and 25% by volume to the biochar compost
- Use a compost calculator to estimate C:N ratio of compost ingredients



Calculating C:N



Klickitat County

[Solid Waste Home Page](#) > [Compost](#) > [Compost Mix Calculator Introduction](#) > Compost Mix Calculator

Compost Mix Calculator

Choose a material. Enter a cubic foot measurement. Press TAB. The Total C:N ratio for your recipe will appear.

Aim for a TOTAL C:N RATIO of 30. (25-30 is good. 20-40 is OK.)

Material	CuFt	LbWet	%H2O	available %C	available %N	Lb C	Lb N	available C:N
Food Waste 15:1	5	277.78	69	37.1	2.5	31.94	2.15	14.84
Straw Wheat 53:1	27	227	12	21.06	0.4	42.08	0.8	52.66
None 0:1	0							
None 0:1	0							
TOTALS:						74.02	2.95	25.08

For a total C:N Ratio of 25:1 mix
5 part(s) Food Waste
27 part(s) Straw Wheat



<http://www.klickitatcounty.org/solidwaste/fileshtml/organics/compostcalc.htm>

Methods

- Construct piles in layers, taking care to add bulk materials and biochar in enough layers to allow natural aeration
- Water both piles the same
- Monitor moisture – it should pass the “squeeze test”
- Make temperature measurements every day

The Squeeze Test – take a handful of material and squeeze. No water should come out, but when you open your hand, there should be enough moisture to hold the material together so it does not fall apart instantly



Biochar Compost Tests

- What are best tests to evaluate biochar compost nutrients?
 - NPK and other nutrients – Lab analysis
 - pH
 - Pot trials
 - Field trials
- What are the best tests to tell us something about microbial life?
 - Enzyme analysis – Lab analysis
 - CO₂ respiration – Lab analysis
 - Chromatograms
- Need to find simplest, cheapest way to evaluate impacts of biochar and biochar composts



Biochar Compost Tests

- What are best tests to evaluate biochar compost nutrients?
 - **NPK and other nutrients – Lab analysis**
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 - Pot trials
 - **Field trials – very difficult to do**
- What are the best tests to tell us something about microbial life?
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 - Chromatograms
- Need to find simplest, cheapest way to evaluate impacts of biochar and biochar composts



pH testing – use paper strips

Supplies:

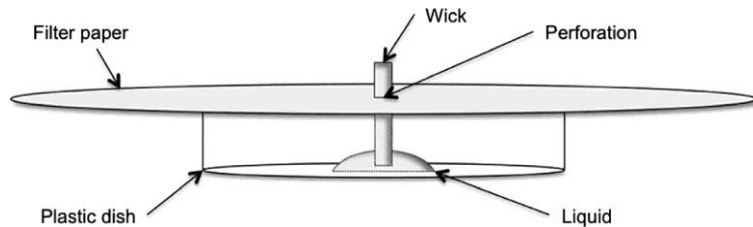
- Quality pH paper from Hydrion
- Distilled water
- Jars with lids
- Dried, ground soil or compost samples

Procedure:

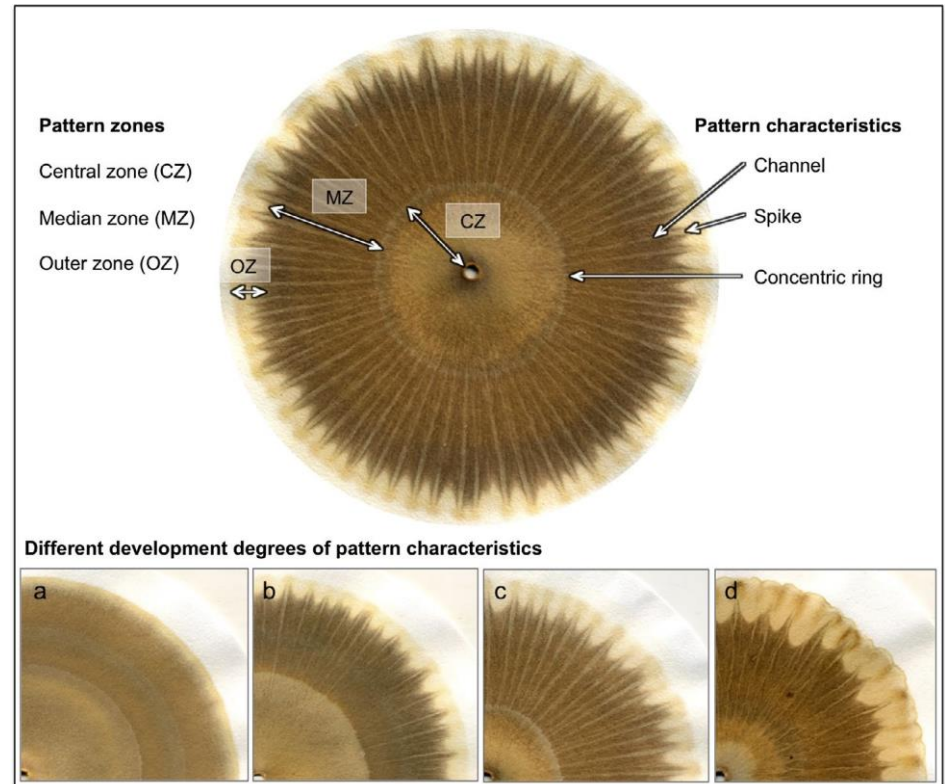
- Add 1 tablespoon of sample and 2 tablespoons of distilled water to jar
- Cap and shake shake shake for one minute
- Let sit for 2 minutes
- Dip pH strip into liquid and compare to color chart



Circular Chromatography



“...there were strong, significant correlations between PCC pattern parameters derived from the three evaluation approaches and many of the here considered soil chemical compounds and characteristics, e.g. **pH, organic matter content, total nitrogen content, assimilable phosphorus and bromine, as well as the contents of sand, clay and silt.** “



More info at SoilChromatograms.com



Kokornaczyk, M. O., Primavera, F., Luneia, R., Baumgartner, S., & Betti, L. (2017). Analysis of soils by means of Pfeiffer's circular chromatography test and comparison to chemical analysis results. *Biological agriculture & horticulture*, 33(3), 143-157.

Chromatograms – Michaels Ranch



Chromatograms – WBA Garden Soil



Pot Trials: Plant Bioassays to Evaluate Biochar Compost



- Useful, along with fertilizer or compost lab analysis, to evaluate biochar compost.
- Adapted from methodology developed by Frank Shields

Pot Trial Protocol

- Simple 2-week test in grow tent
- Cucumber seeds
- Germination percent
- Count growth nodes
- Dry and weigh above ground biomass



Equipment Needed: Pot Trial Protocol

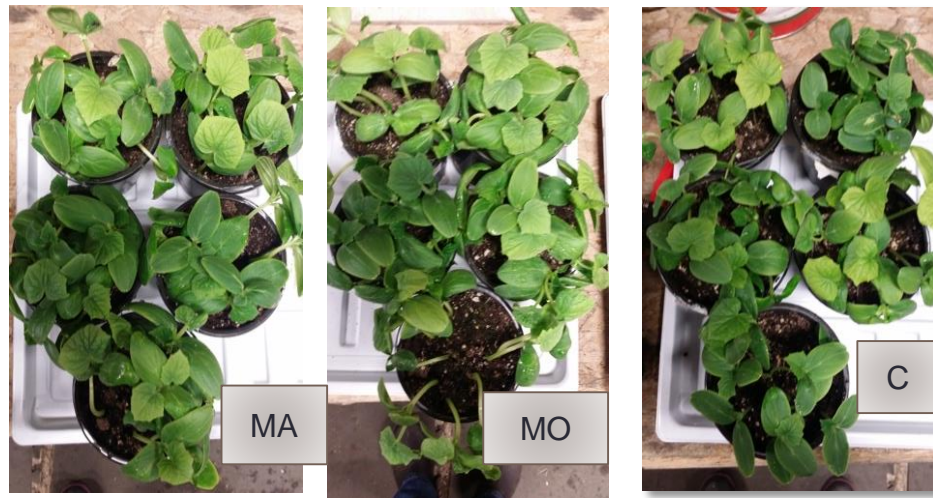
- Grow tent (used for cannabis, with lights, timer, exhaust fan) or greenhouse.
- Scale accurate to .01g
- Food dehydrator
- Plastic pots
- Plastic drink cups for humidity control
- Mesh bags for drying
- Plain peat potting soil for control



Michaels Ranch

Treatments:

- MA – Cattle manure mixed with high carbon ash (2016 pile, not mixed in barn) and stored in large pile for 6 months (pH 9.44)
- MO – Cattle manure stored in large pile for 6 months (pH 7.50)
- C - Control



Treatment	Germination (%)	Secondary Leaves (count)	Biomass (grams)
MA	96	41	1.96
MO	100	43	2.07
C	98	38	1.58



Siskiyou Alpaca

Treatments:

- HB – Pacapoo compost with high biochar (12.5%) built on 6-29-16, harvested 12-13-`6
- NB – Pacapoo compost from otherwise identical pile with no biochar
- C - Control



From L to R: 12.5% biochar, No biochar, Control

Treatment	Germination (%)	Secondary Leaves (count)	Biomass (grams)
HB	96	78	2.16
NB	100	54	2.12
C	98	56	1.70



Chromatograms – Siskiyou Alpaca



Pacapoo Only

3.6% Biochar Pacapoo

12.5% Biochar Pacapoo



Don Morrison's Compost

We picked char particles out of the compost and tested them in soil mixes



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Organic coatings on biochar surfaces have a growth stimulating effect

Now you have the tools



Questions?



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- Project Development

