Is Black the New Green? The Potential of Biochar for Tree Management

Kelby Fite, Ph.D.

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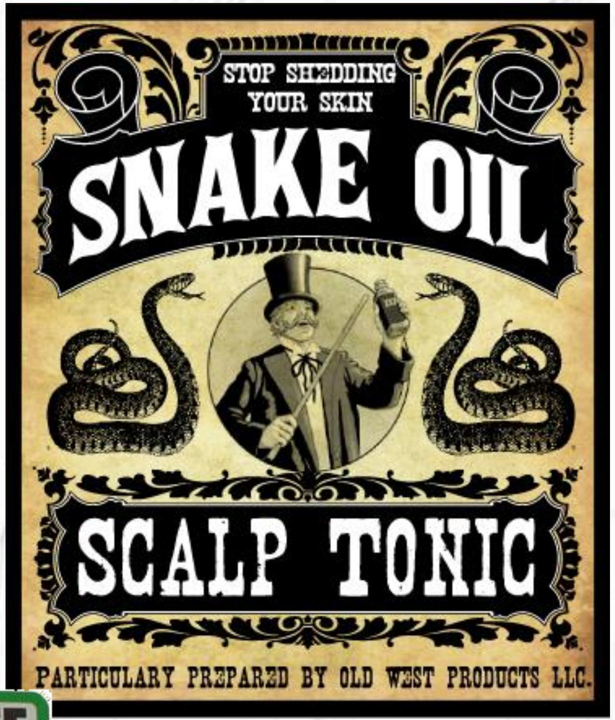
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The Potential of Biochar as a Soil Amendment

“Terra preta” in Amazonian agriculture was amended with charcoal

Potentially hundreds or thousands of years old

High OM and available nutrients

Courtesy of J Thies

Figure 2. Dark earth from the Amazon, with biochar which accumulated about 800 years before present and still shows a distinctly black color, indicating the high stability of biochar (compare black topsoil with the yellow underlying material in the pit).

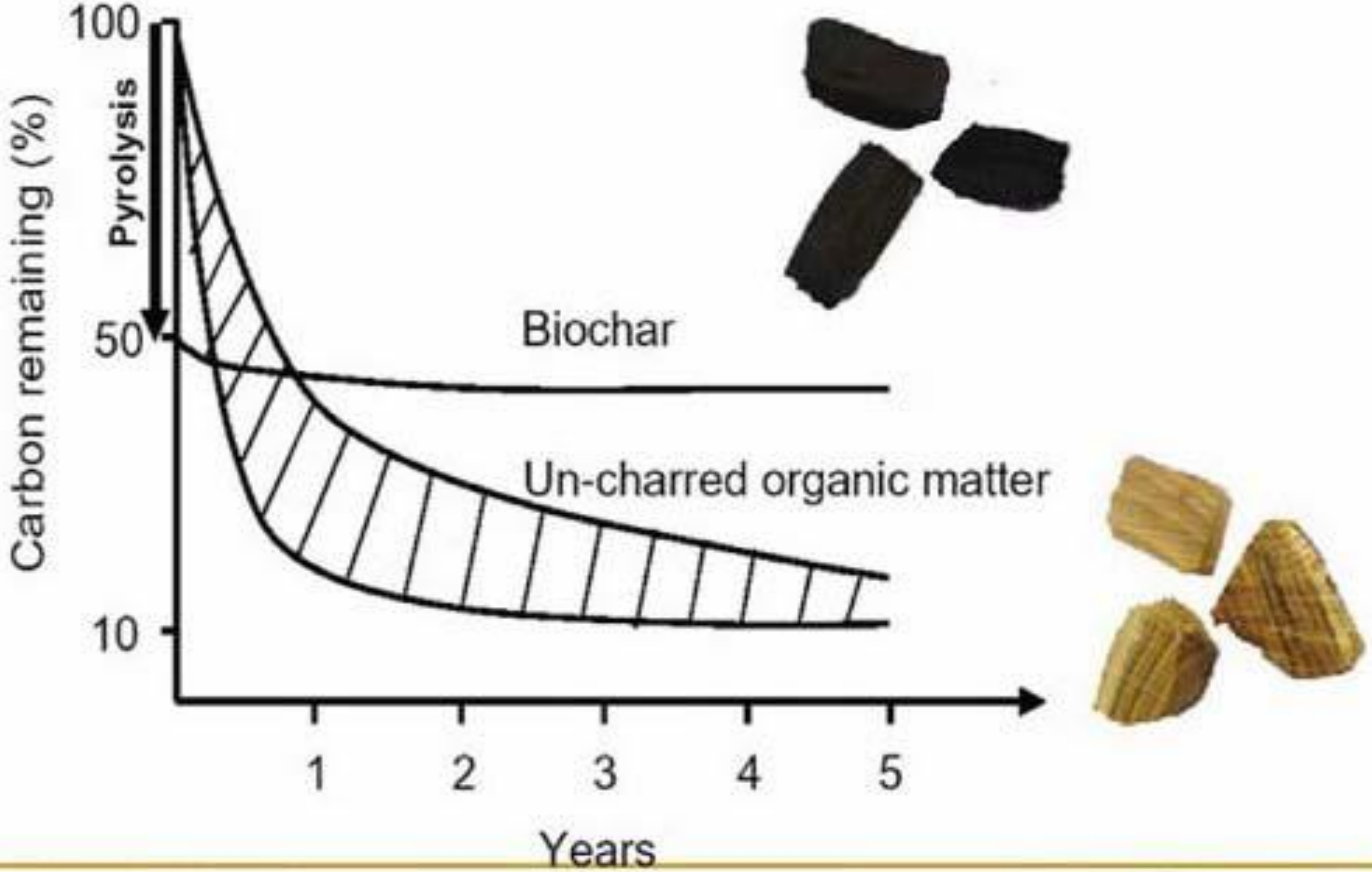
A Brief Compend of American Agriculture by R.L. Allen (1847):

Charcoal dust [drilled in with the seed] has been found to increase the early growth from four to ten-fold (p. 150).

Scattered over the ground … [charcoal] absorbs and condenses the nutritive gases within its pores, to the amount of from 20 to over 80 times its own bulk. ... Charcoal … often checks rust in wheat, and mildew in other crops; and in all cases mitigates their ravages, where it does not wholly prevent them (p. 45).

A dressing of charcoal has in many instances, been found an adequate preventative [of rust]; and so beneficial has it proved in France, that it has been extensively introduced there for the wheat crop (p. 109).

The essential stability of biochar



Lehmann et al., 2006, *Mitigation and Adaptation Strategies for Global Change* 11, 403-427

Cornell University

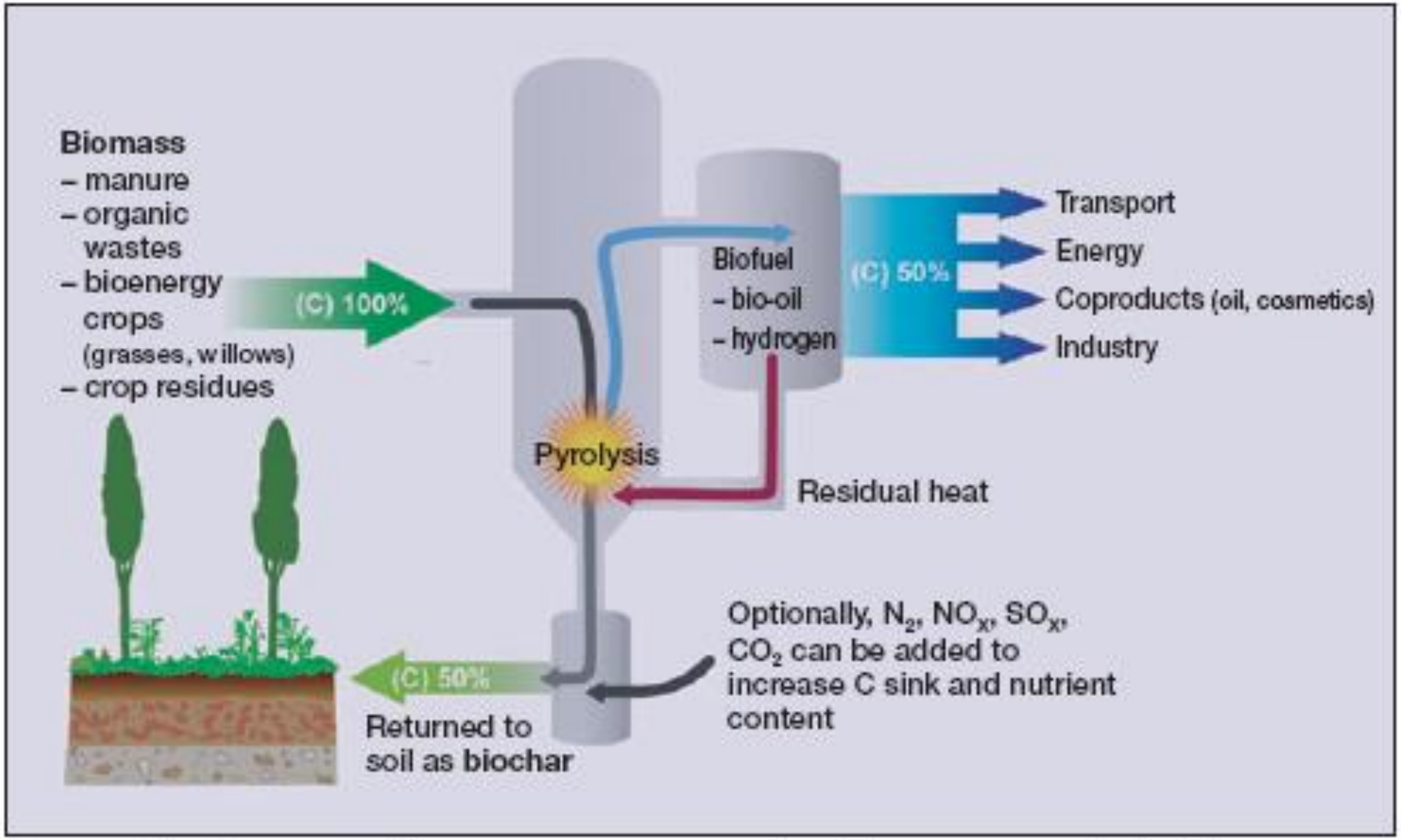


Figure 1. *Concept of low-temperature pyrolysis bio-energy with biochar sequestration. Typically, about 50% of the pyrolyzed biomass is converted into biochar and can be returned to soil.*

Could chicken manure help curb climate change?

'Biochar' is seen as cheap solution

By Brian Winter
USA TODAY

USA TODAY / CBS REPORTS: WHERE AMERICA STANDS

A series of reports by USA TODAY and CBS News is exploring issues facing the nation during the next decade.

WARDENSVILLE, W.Va. — Here's a low-cost solution to global warming: chicken manure.

At Josh Frye's poultry farm in West Virginia, the chicken waste is fed into a large, experimental incinerating machine. Out comes a charcoal-like substance known as "biochar" — which is not only an excellent fertilizer, but also helps keep carbon in the soil instead of letting it escape into the atmosphere, where it acts as a greenhouse gas.

Former vice president and environmental advocate Al Gore calls biochar "one of the most exciting new strategies" available to stop climate change. For Frye, it means that, before long, "the chicken poop could be worth more than the chickens themselves."

"I thought it was crazy at first, and my wife still thinks it's nuts," admits Frye, 44. Yet he has sold nearly $1,000 worth of biochar to farmers as far away as New Jersey, and plans to sell much more as he refines production. Venture capitalists, soil scientists and even members of Congress have all come to Frye's farm to see whether his example can be repeated.

Cover story

Techniques such as biochar may represent the best compromise between what's good for the environment and what's affordable during the recession, says Rep. Shelley Moore Capito, R-W.Va., who visited Frye's farm in August.

As political support in Washington fades for more expensive pollution-fighting mea-

Please see COVER STORY next page ▸

By Jack Gruber, USA TODAY

Lower propane costs: Josh Frye uses manure and a gasifier to heat the chicken house where he raises hatchlings.

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8 weird ways to save the Earth

Biochar

7 of 8 | Back | Next

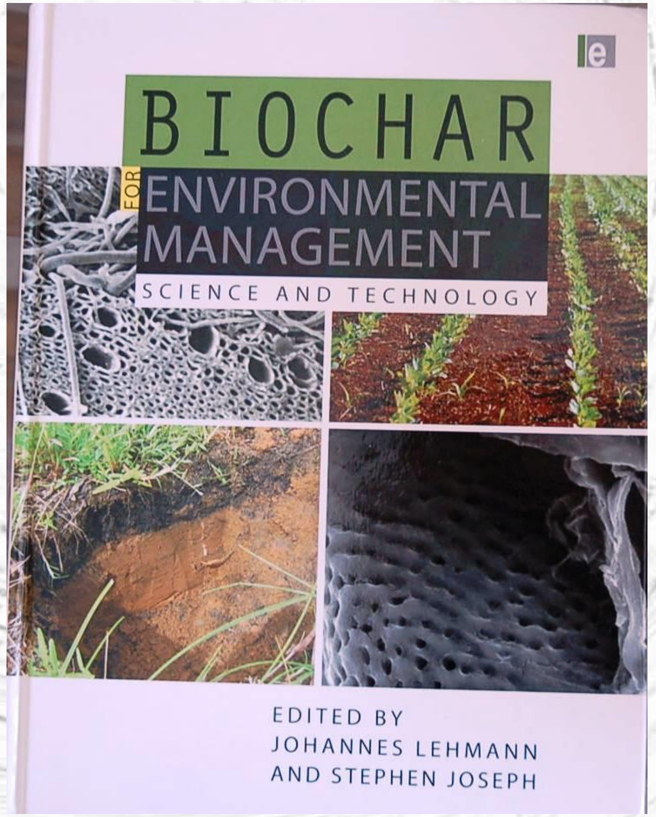
Currently farmers, foresters, and others that dispose of plants and trees usually leave them in the field to rot, or they burn them. Both those actions release carbon into the atmosphere.

How it works: This plan calls for farmers and the like to feed their waste into a machine that turns it into charcoal, seen here. The charcoal - or biochar - is then buried in the soil.

That would keep up to 40% of the carbon in the plant out of the atmosphere, and make the soil richer at the same time, said Jim Fournier, president of Biochar Engineering Corp.

COURTESY: BIOCHAR ENGINEERING CORP.

Why it might not work: Questions remain over whether biochar could absorb enough carbon to make a difference in global warming.

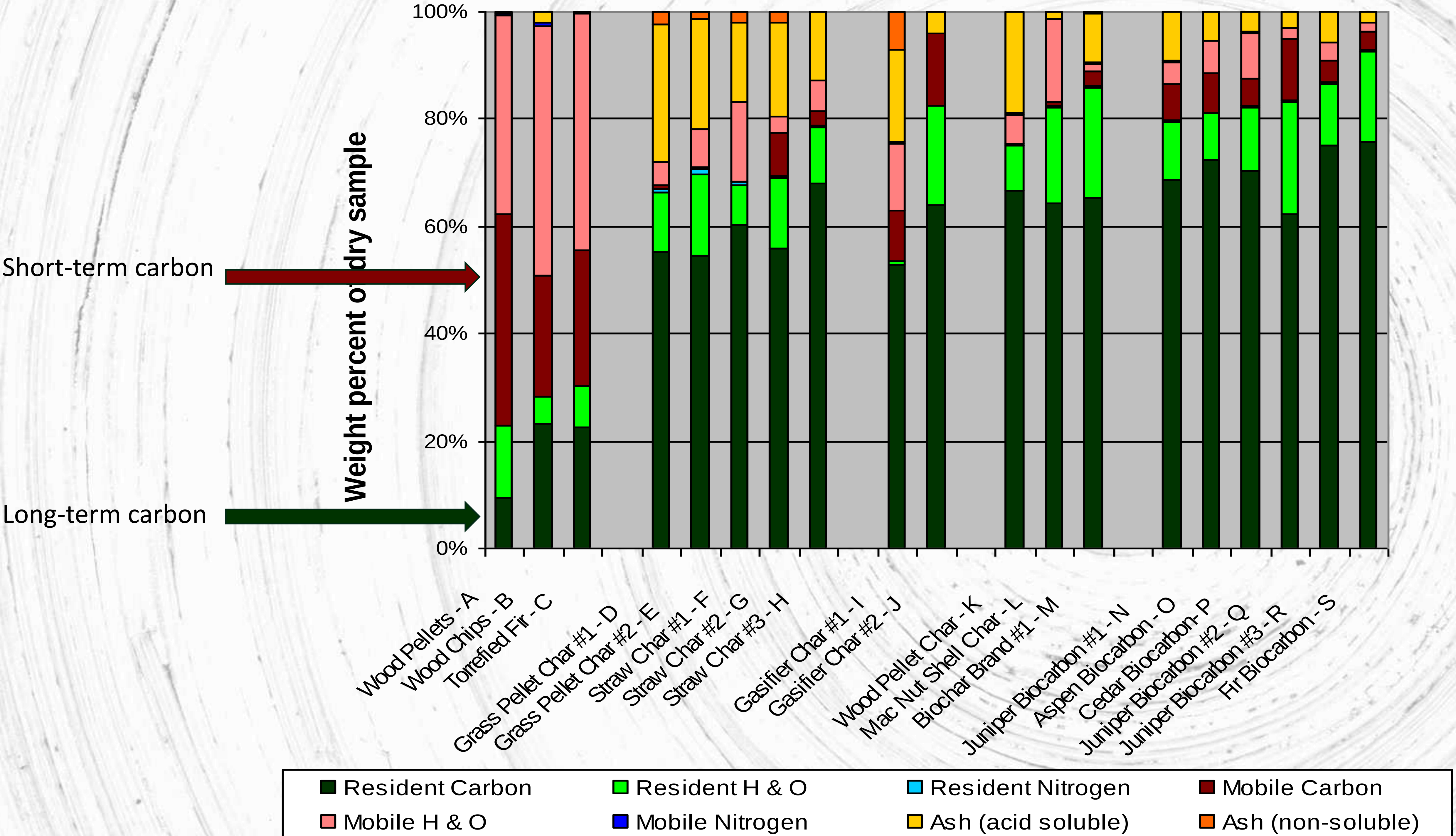


Waste materials have potential to become quality biochar

Principal Constituents of Biochar:

- Moisture (as delivered)
- Ash (as delivered and from what)
- **Mobile Matter versus Resident Matter**
  - Mobile - can migrate out of the char
  - Resident - stays with the char & soil
  - Matter = Carbon and H&O portions
  - Carbon is measured for CO_2 sequestration, but plants care about soluble organics and plant nutrients available in the soil

Buyer Beware!



Short-term carbon
Long-term carbon
Weight percent of dry sample
100%
80%
60%
40%
20%
0%
Wood Pellets - A
Wood Chips - B
Torrefied Fir - C
Grass Pellet Char #1 - D
Grass Pellet Char #2 - E
Straw Char #1 - F
Straw Char #2 - G
Straw Char #3 - H
Gasifier Char #1 - I
Gasifier Char #2 - J
Wood Pellet Char - K
Mac Nut Shell Char - L
Biochar Brand #1 - M
Juniper Biocarbon #1 - N
Aspen Biocarbon - O
Cedar Biocarbon - P
Juniper Biocarbon #2 - Q
Juniper Biocarbon #3 - R
Fir Biocarbon - S
Resident Carbon
Resident H & O
Resident Nitrogen
Mobile Carbon
Mobile H & O
Mobile Nitrogen
Ash (acid soluble)
Ash (non-soluble)

What causes the variations in Mobile and Resident Matter?

What it was made from and the way it was made.

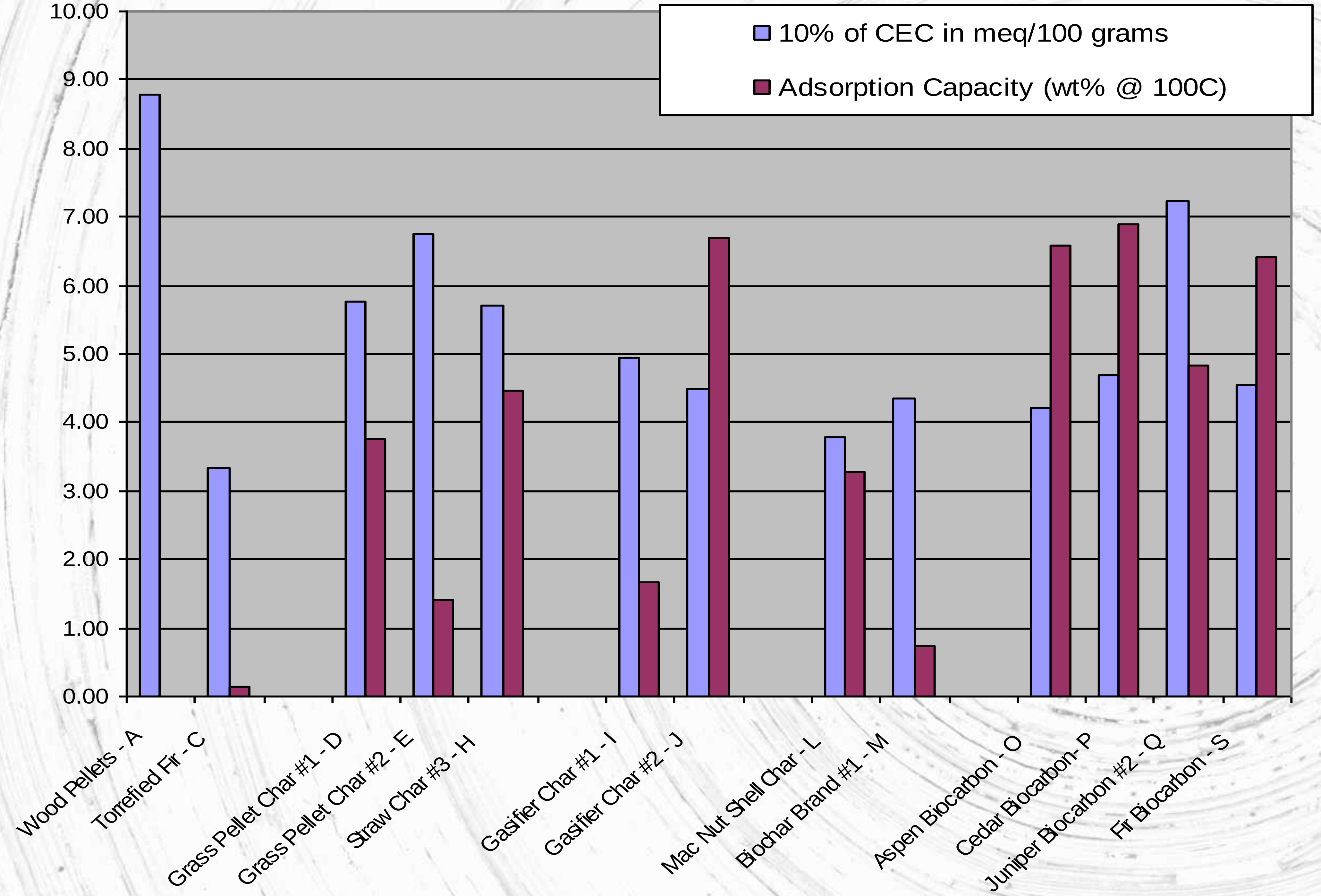
Principal Constituents of Biochar:

- Moisture (as delivered)
- Ash Content (as delivered and from what)
- Mobile Matter versus Resident Matter

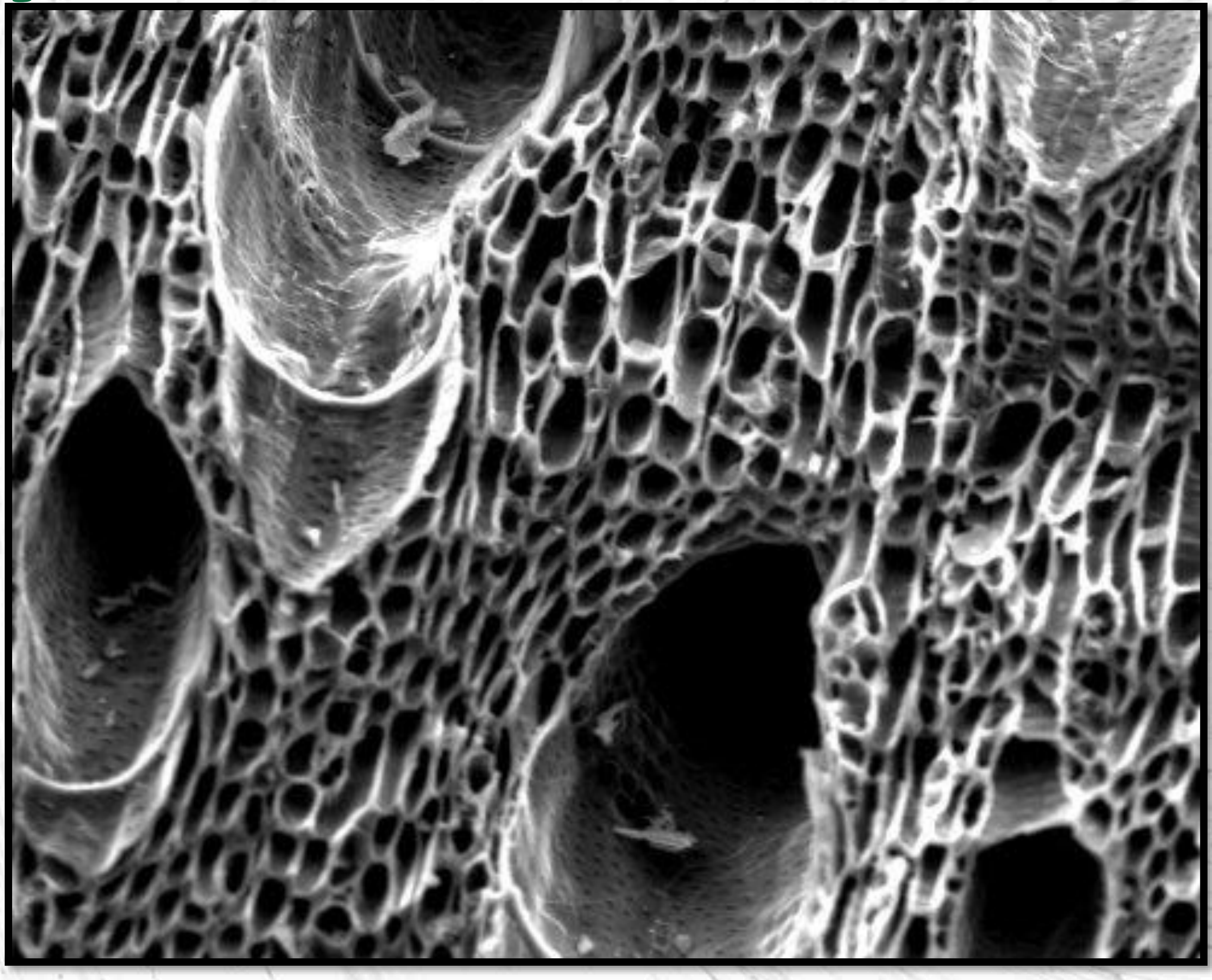
- **Cation Exchange Capacity**

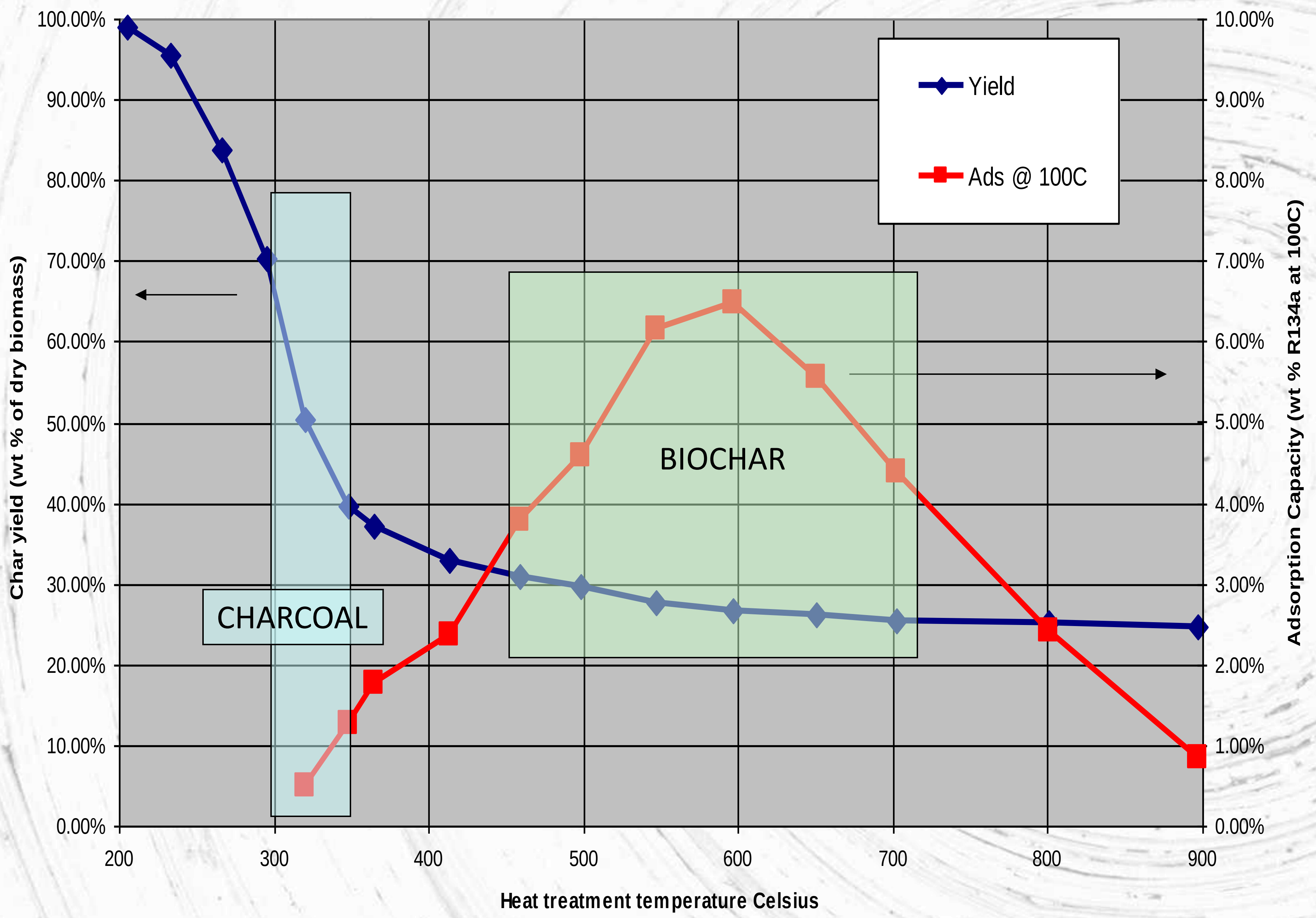
- **Adsorption Capacity**

Buyer Beware!


10% of CEC in meq/100 grams
Adsorption Capacity (wt% @ 100C)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Wood Pellets - A
Torrefied Fir - C
Grass Pellet Char #1 - D
Grass Pellet Char #2 - E
Straw Char #3 - H
Gasifier Char #1 - I
Gasifier Char #2 - J
Mac Nut Shell Char - L
Biochar Brand #1 - M
Aspen Biocarbon - O
Cedar Biocarbon- P
Juniper Biocarbon #2 - Q
Fir Biocarbon - S

High surface area and porosity are keys to biochar effects



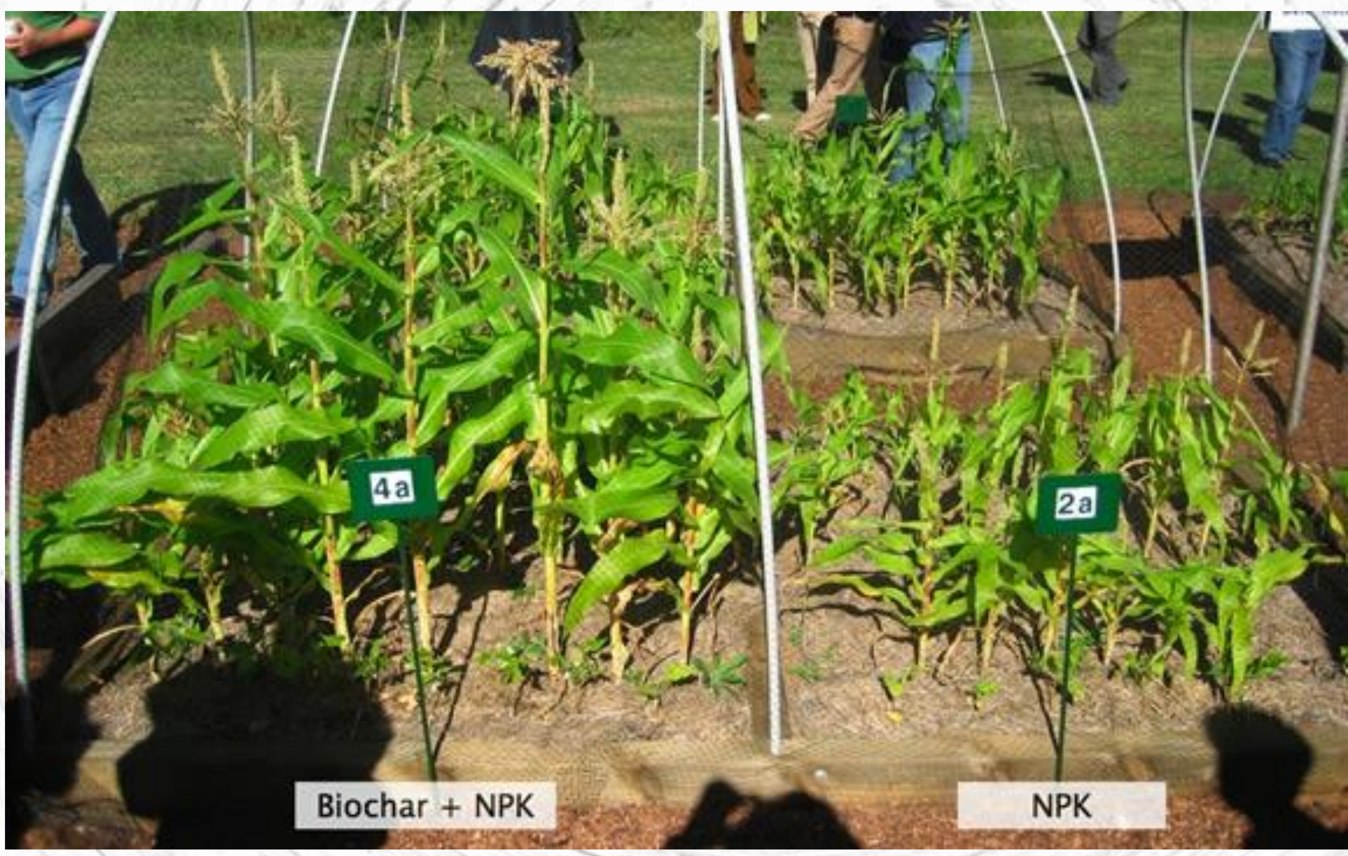


Yield
Ads @ 100C
CHARCOAL
BIOCHAR
Char yield (wt % of dry biomass)
Adsorption Capacity (wt % R134a at 100C)
Heat treatment temperature Celsius
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
10.00%
9.00%
8.00%
7.00%
6.00%
5.00%
4.00%
3.00%
2.00%
1.00%
0.00%
200
300
400
500
600
700
800
900

Char contains benefits of soil organic matter and is more stable – no nutrition!

- Increase CEC
- Improve water retention
- Improve fertilizer effectiveness

Benefits are just now being realized in agriculture



Bruno Glaser · Johannes Lehmann · Wolfgang Zech

Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal – a review

Biology and fertility of soils 35, 219-230

Table 1 Relation between charcoal amendments to soil and crop response

Treatment	Amendment ($Mg\ ha^{-1}$)	Biomass production (%)	Plant height (%)	Root biomass (%)	Shoot biomass (%)	Plant type	Soil type	Reference
Control	–	100	100	–	–	Bauhinia wood	Alfisol/Ultisol	Chidumayo (1994)
Charcoal	Unknown	113	124	–	–	Bauhinia wood	Alfisol/Ultisol	
Control	–	100	–	–	–	Soybean	Volcanic ash soil, loam	Kishimoto and Sugiura (1985)
Charcoal	0.5	151	–	–	–	Soybean	Volcanic ash soil, loam	Iswaran et al. (1980)
Charcoal	5.0	63	–	–	–	Soybean	Volcanic ash soil, loam	Kishimoto and Sugiura (1985)
Charcoal	15.0	29	–	–	–	Soybean	Volcanic ash soil, loam	
Control	–	100	–	–	–	Pea	Dehli soil	Iswaran et al. (1980)
Charcoal	0.5	160	–	–	–	Pea	Dehli soil	
Control	–	100	–	–	–	Moong	Dehli soil	
Charcoal	0.5	122	–	–	–	Moong	Dehli soil	
Control	–	100	–	100	–	Cowpea	Xanthic Ferralsol	Glaser et al. (2002a, 2002b)
Charcoal	33.6	127	–	–	–	Oats	Sand	
Charcoal	67.2	120	–	–	–	Rice	Xanthic Ferralsol	
Charcoal	67.2	150	–	140	–	Cowpea	Xanthic Ferralsol	
Charcoal	135.2	200	–	190	–	Cowpea	Xanthic Ferralsol	
Control	–	100	100	100	100	Maize	Alfisol	Mbagwu and Piccolo (1997)
Coal humic acid	0.2	118	114	122	114	Maize	Alfisol	
Coal humic acid	2.0	176	145	186	166	Maize	Alfisol	
Coal humic acid	20.0	132	125	144	120	Maize	Alfisol	
Control	–	100	100	100	100	Maize	Inceptisol	
Coal humic acid	0.2	125	119	122	127	Maize	Inceptisol	
Coal humic acid	2.0	186	148	198	173	Maize	Inceptisol	
Coal humic acid	20.0	139	131	147	130	Maize	Inceptisol	
Control	–	100	100	100	–	Sugi trees	Clay loam	Kishimoto and Sugiura (1985)
Wood charcoal	0.5	249	126	130	–	Sugi trees	Clay loam	
Bark charcoal	0.5	324	132	115	–	Sugi trees	Clay loam	
Activated charcoal	0.5	244	135	136	–	Sugi trees	Clay loam	

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Cryptomeria

Kishimoto and Sugiura (1985)

Arboriculture & Urban Forestry 2022. 48(3):176–202
https://doi.org/10.48044/jauf.2022.014

The Influence of Biochar Soil Amendment on Tree Growth and Soil Quality: A Review for the Arboricultural Industry

By Emma Schaffert, Martin Lukac, Glynn Percival, and Gillian Rose

Table 1. Summary of the main characteristics of biochar, as affected by raw material used for pyrolysis. NC = not communicated.

Biochar raw material	pH	C:N ratio	CEC (cmol [+] kg^{-1})	EC (dS m^{-1})	Ash content (%)	Bulk density (g cm^{-3})
Pelletized sawdust (Sackett et al. 2015; Lin et al. 2017; Fields-Johnson et al. 2018; Ow et al. 2018; Rafique et al. 2020)	6.3, 7.5, 8.3	10.5 – 13.2	6.2 – 6.4	3.3	3.11 – 25.7	0.13
Wood residues (coniferous) (Pluchon et al. 2014; Sarauer and Coleman 2018; Fujita et al. 2020; Phillips et al. 2020)	6.2 – 8.3	66.9	18.6 – 22.9	2.2 – 3.7	40.3 (at 980 °C)	0.17 – 0.44
Wood residues (hardwood) (Di Lonardo et al. 2017; Safaei Khorram et al. 2019; Shan and Coleman 2020; Somerville et al. 2020)	6.8 – 9.7	60.4 – 138	30	2.6	19.8	0.33 – 0.42
Chicken manure (Domingues et al. 2017; Lin et al. 2017)	9.8 – 11.9	11.9	41	5.8 – 7.4	48.8 – 56	NC
Rice husk (Häring et al. 2017; Amirahmadi et al. 2020; Wiersma et al. 2020)	8.1 – 9.1	70.7	18.28	NC	45.2	0.18 – 0.22
Nut husk (Rajkovich et al. 2012; Lefebvre et al. 2019)	7.66 – 9.6	158 – 181	5.9 – 11.8	1.42 – 1.60	1.69 – 7.80	NC
Bamboo (Ye et al. 2015)	8.5 – 10.2	24.48 – 28.92	NC	NC	9.5 – 14.2	NC
Orchard prunings (Ventura et al. 2014; Genesio et al. 2015; Sorrenti and Toselli 2016)	9.8	63.53	101	NC	NC	0.33
Sewage sludge (Paneque et al. 2016; Silva et al. 2016)	7.50, 8.41	6.12	NC	7.29	25.6	NC

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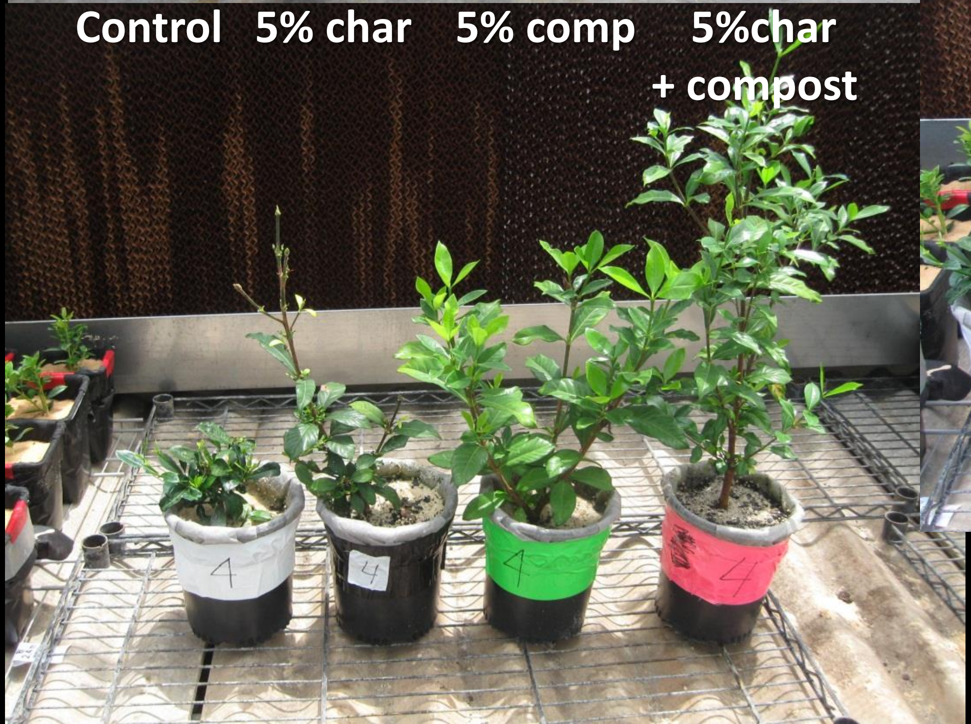
Blending with compost always outperforms straight char



What will biochar do in street tree pits?

The Morton Arboretum

TREE FUND
Tree Research & Education Endowment Fund

Hyland Johns grant

Urban site: City tree pits in Bucktown neighborhood in Chicago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Arboriculture & Urban Forestry 2022. 48(3):203–214
https://doi.org/10.48044/jauf.2022.015

An Arboriculture Treatment of Biochar, Fertilization, and Tillage Improves Soil Organic Matter and Tree Growth in a Suburban Street Tree Landscape in Bolingbrook, Illinois, USA

By Bryant C. Scharenbroch, Kelby Fite, and Michelle Catania

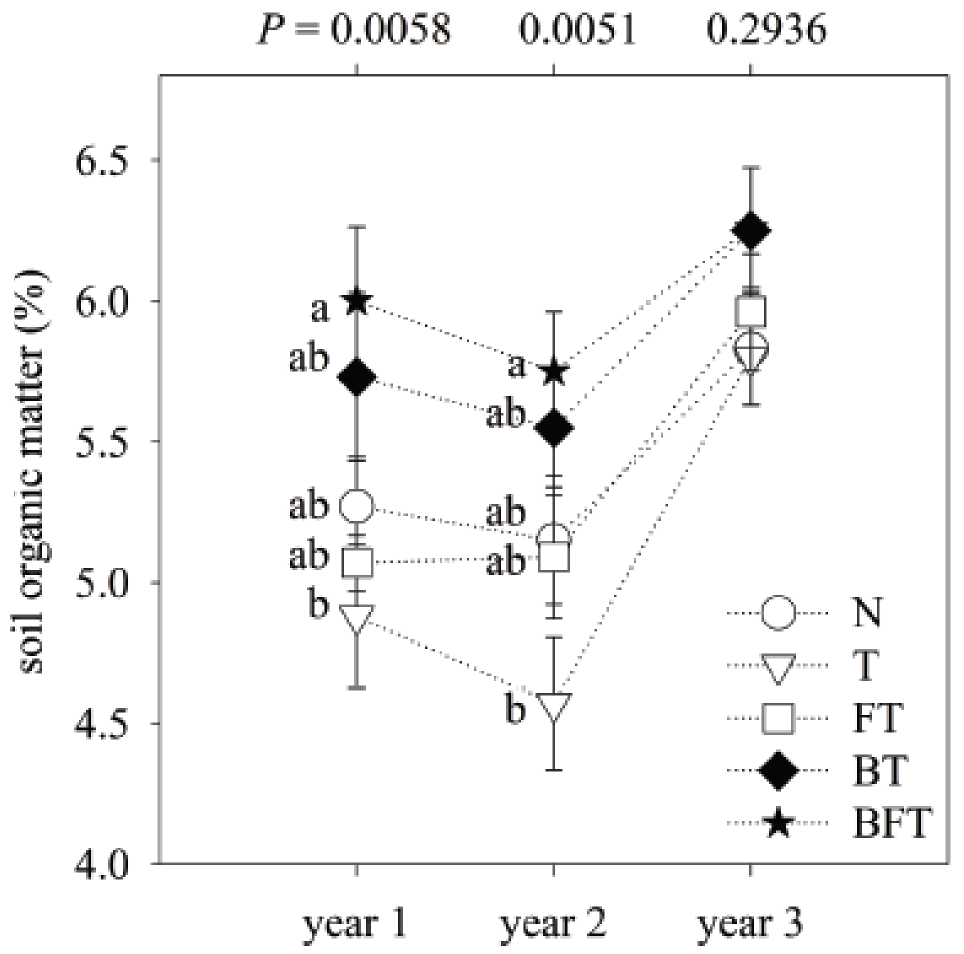


Figure 1. Temporal responses of soil organic matter. Mean, standard errors of the means, and Tukey's HSD post hoc tests for soil organic matter. Abbreviations: null = N, tillage = T, fertilization + tillage = FT, biochar + tillage = BT, and biochar + fertilization + tillage = BFT.

Can biochar affect pest resistance?

Disease Control and Pest Management

Induction of Systemic Resistance in Plants by Biochar, a Soil-Applied Carbon Sequestering Agent

Yigal Elad, Dalia Rav David, Yael Meller Harel, Menahem Borenshtein, Hananel Ben Kalifa, Avner Silber, and Ellen R. Graber

First, second, third, fourth, and fifth authors: Department of Plant Pathology and Weed Research, Institute of Plant Protection, The Volcani Center, Agricultural Research Organization, and sixth and seventh authors: Department of Soil Chemistry, Plant Nutrition and Microbiology, Institute of Soil, Water and Environmental Sciences, The Volcani Center, Agricultural Research Organization, Bet Dagan 50250, Israel.

Accepted for publication 12 May 2010.

Phytopathology Vol. 100, No. 9, 2010

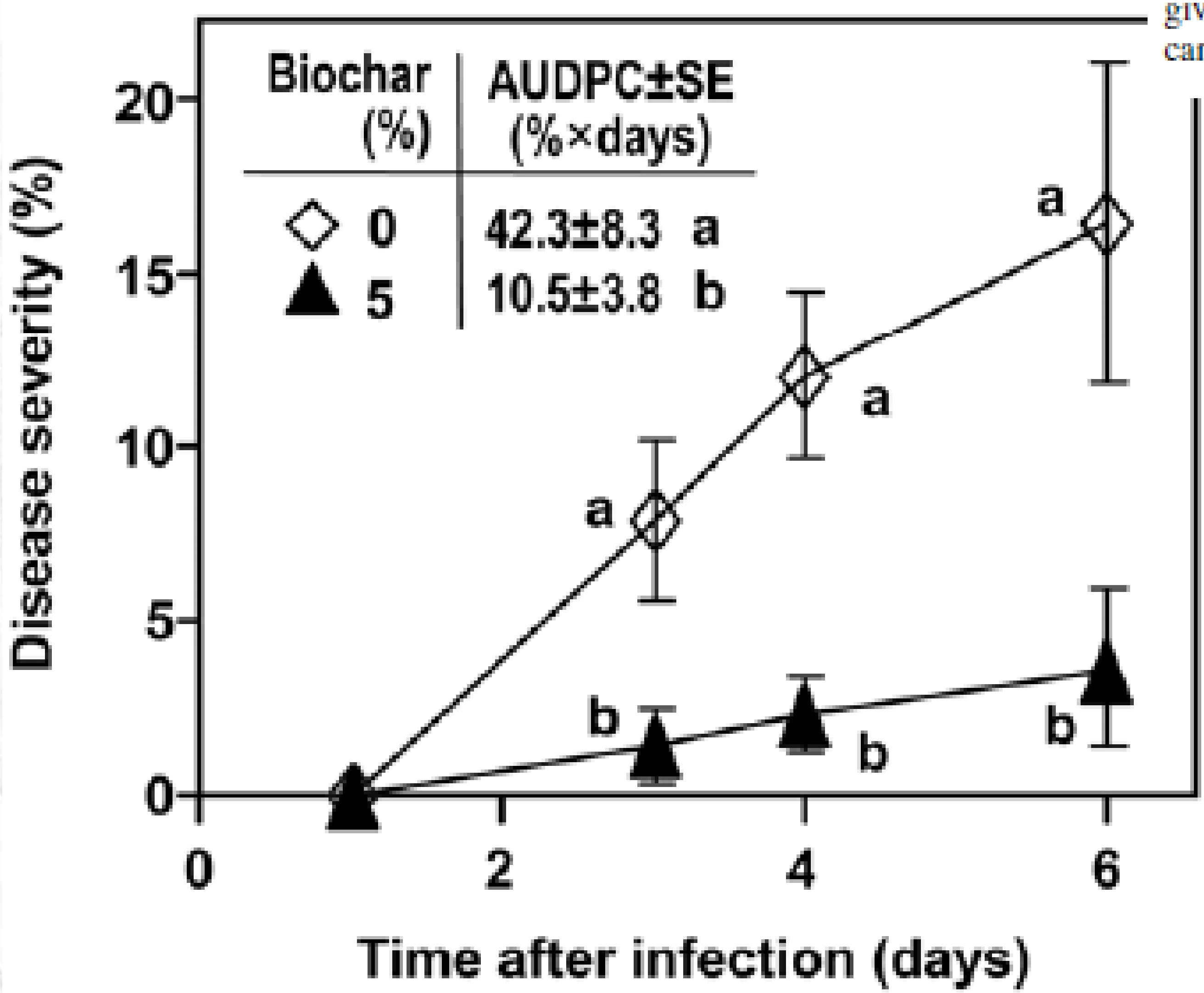


Fig. 3. Effect of biochar mixed in potting medium on development of gray mold (*Botrytis cinerea*) on attached leaves of tomato plants 21 days after planting. Disease is presented as percentage of maximal severity values following inoculation with drops of conidia suspension and as area under the disease progress curve ± standard error (AUDPC ± SE) through 6 days. Plants were incubated at 20 ± 1°C, 97 ± 3% relative humidity, and 1,020 lux light intensity. Bars represent the standard error of the mean of eight replicates. At a given sampling date data points labeled by a common letter are not significantly different according to Fisher's protected least significant difference test.

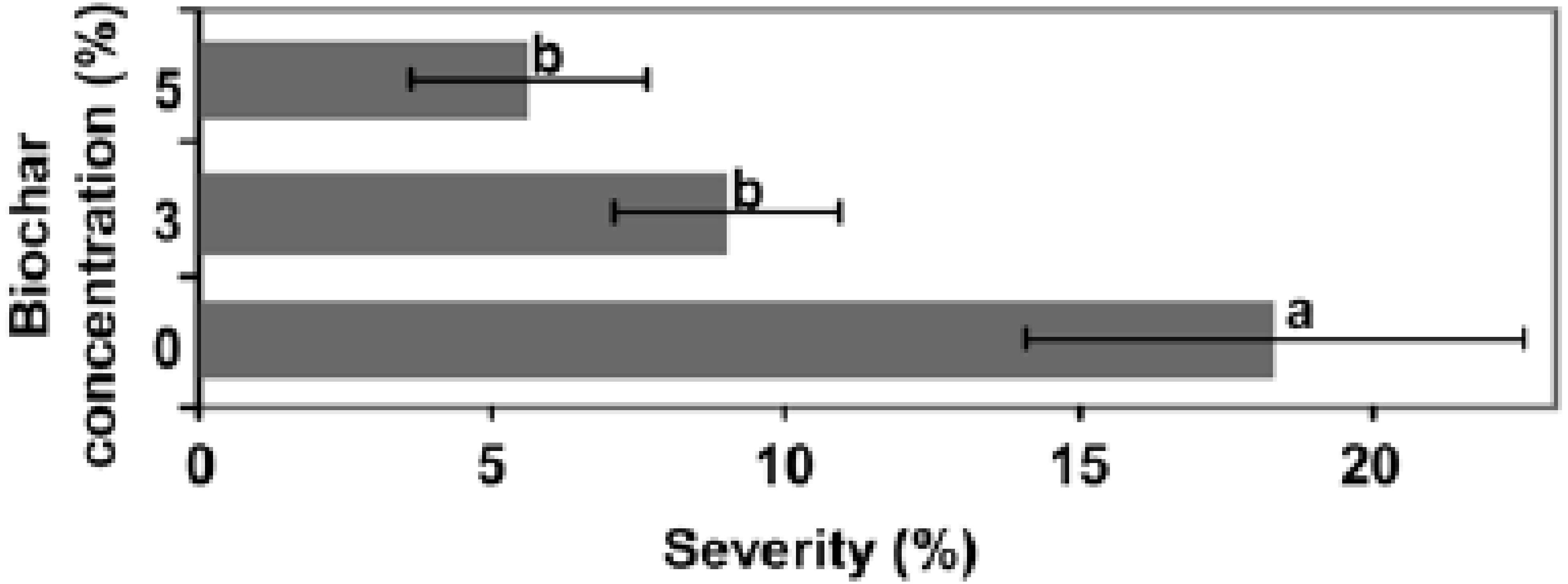


Fig. 5. Effect of biochar in potting medium on symptoms of broad mite (*Polyphagotarsonemus latus*) on pepper plants 57 days after planting. Severity is presented as percentage of plant damaged. Bars represent the standard error of each mean. Plants were incubated at 20 ± 1°C, 97 ± 3% relative humidity, and 1,020 lux light intensity. Each mean is an average of five replicates. Treatments followed by a common letter are not significantly different according to Fisher's protected least significant difference test.

Explanations?

- Toxic residue (tars, glycols, acids)
- Microbial population shifts

Importance of Microorganisms for Plant Physiology

We all know about mycorrhizal fungi

Review

Biochar effects on soil biota – A review

Johannes Lehmann[a,*], Matthias C. Rillig[b], Janice Thies[a], Caroline A. Masiello[c], William C. Hockaday[d], David Crowley[e]

Soil Biology & Biochemistry 43 (2011) 1812–1836

Biochar amendment consistently increased mycorrhizal colonization of roots

Also shifted soil microbial communities, favored populations of known beneficial groups

Biochar has shown preliminary benefits for managing *phytophthora* root rot

Vinca and Gardenia inoculated with *Phytophthora*

Control

Compost

Biochar

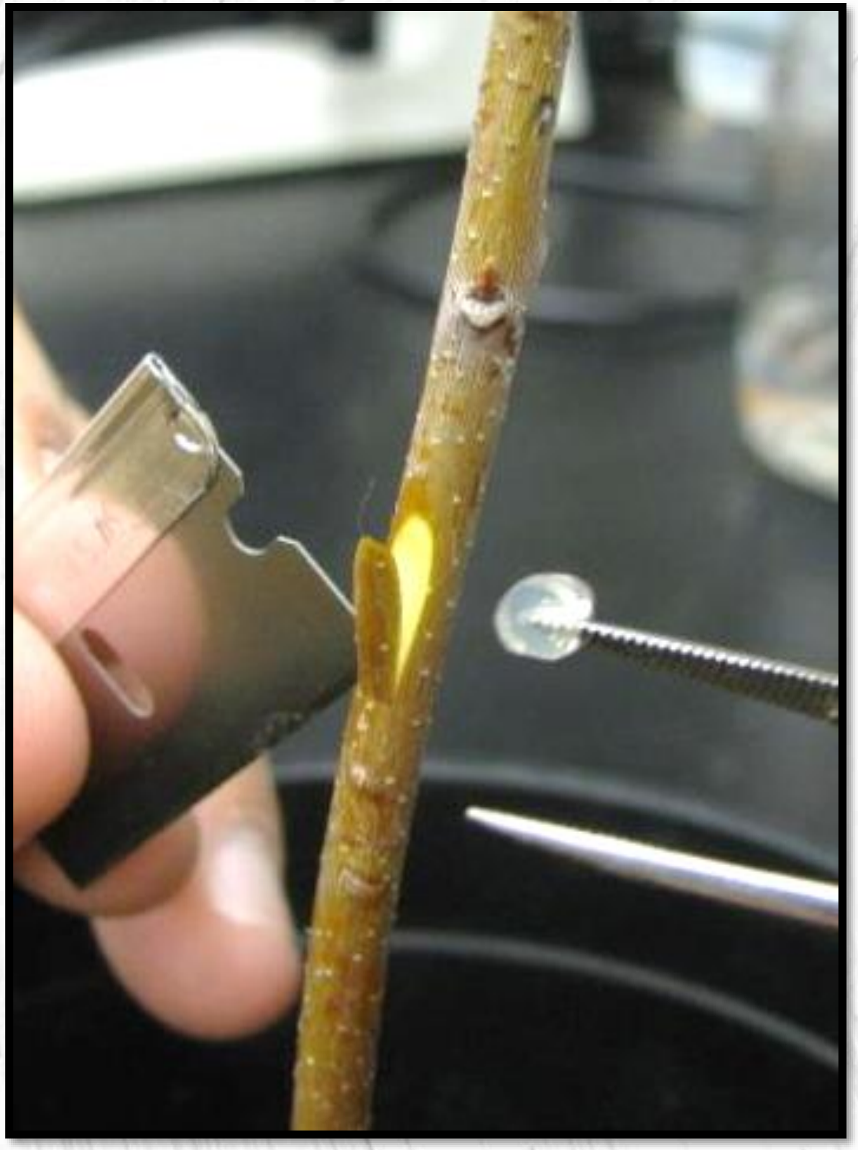

High Biochar


After tilling

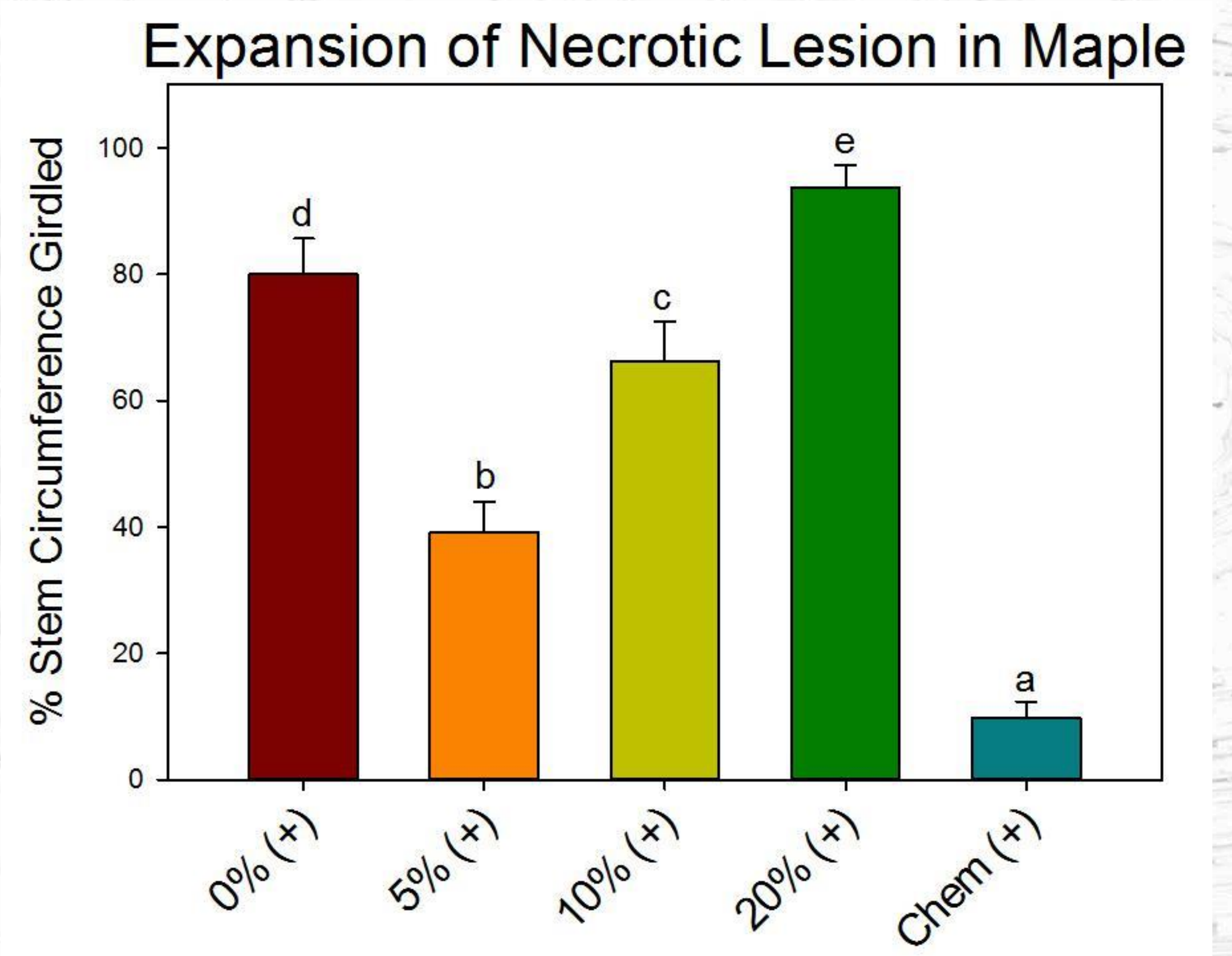

Biochar + compost
No amendment

Red Oak Seedlings – Drew Zwart UW

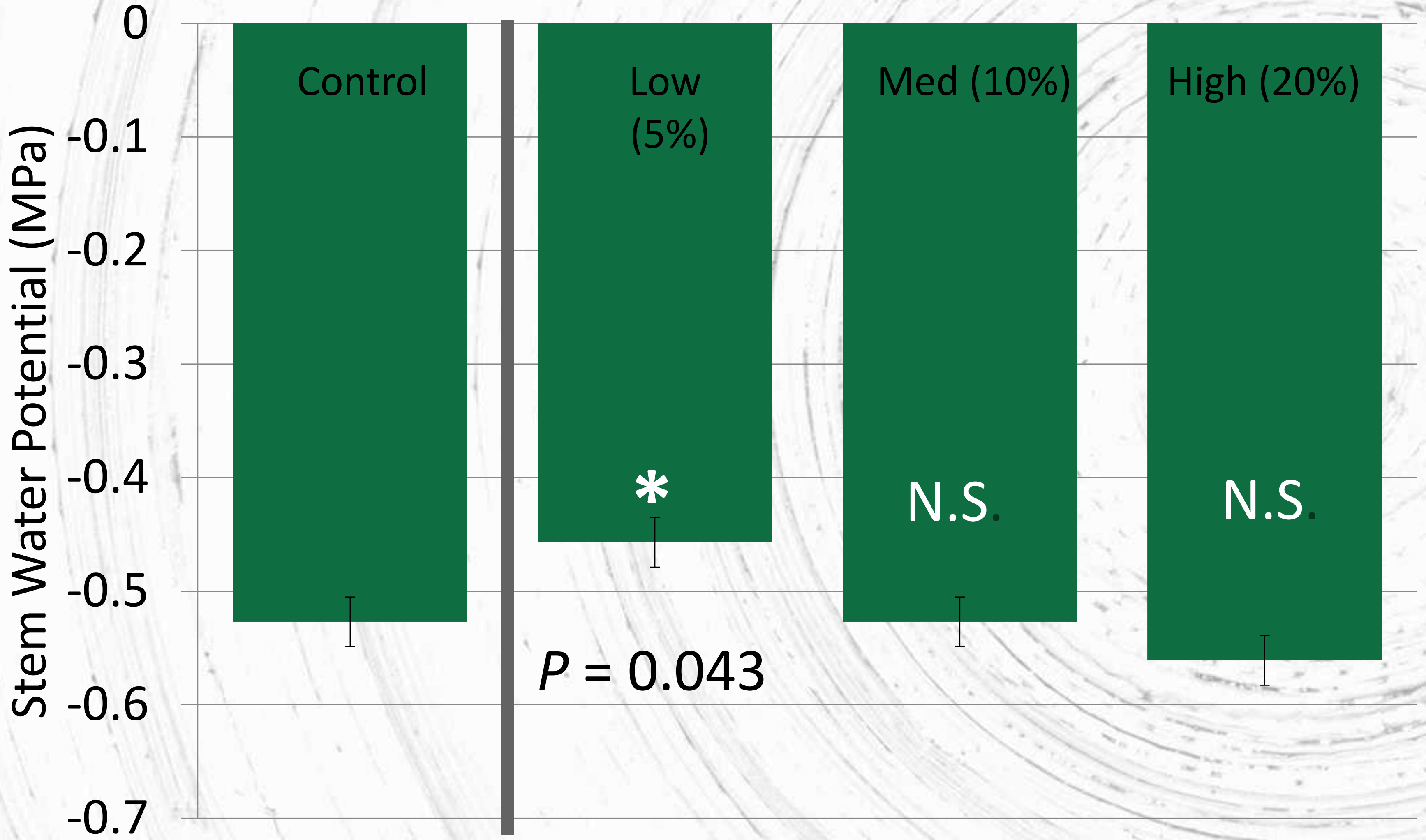
- Potted in 0% (control), 5%, 10%, 20% biochar
- Wound inoculated with agar plug *P. cinnamomi*
- Measured vertical lesion expansion and % circumference girdled based on bark discoloration



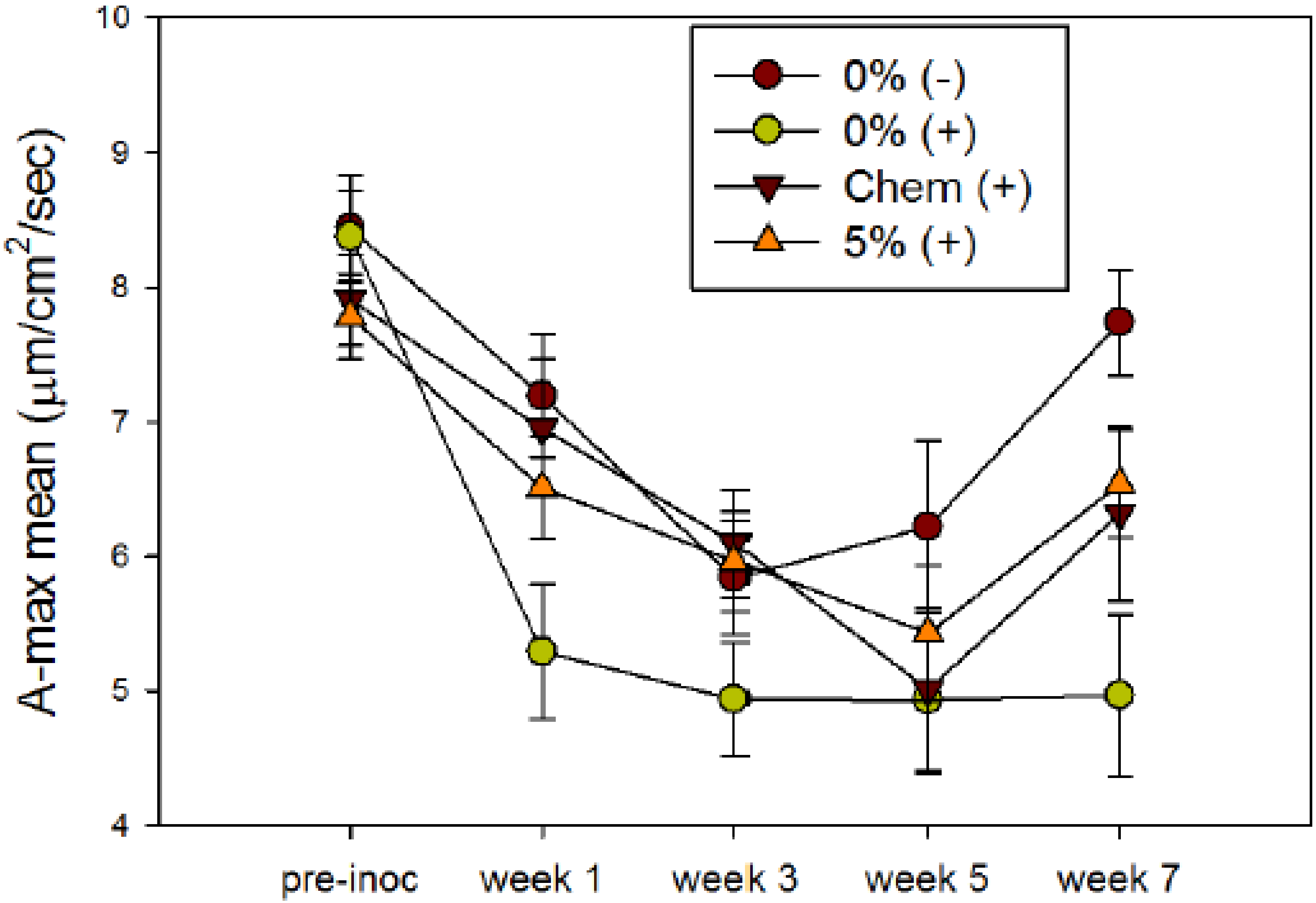
Disease Progression (girdling %) was reduced with biochar and further reduced with phosphite



Results- Stem water potential

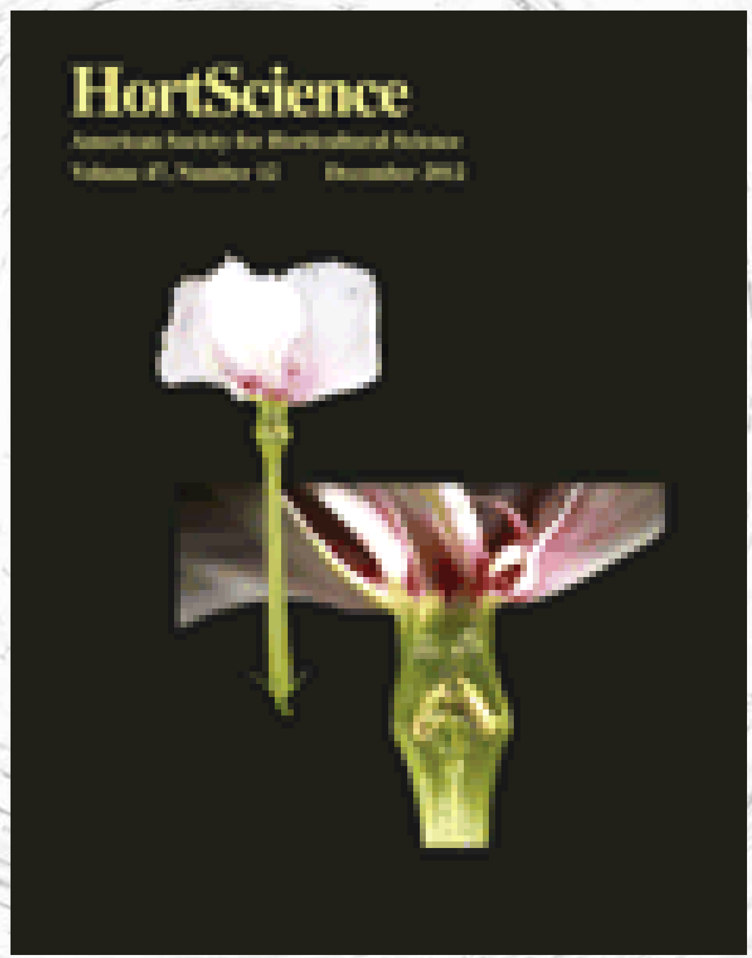


Maximum assimlation rate of CO_2 (A) over time



Zwart and Kim
December 2012 HortScience

Biochar Amendment Increases Resistance to Stem Lesions Caused by Phytophthora spp. in Tree Seedlings



What DOESN'T biochar do?

- Immediate fertility effects
  - Need to add fert and/or compost with biochar for short term effects
- Always act the same
  - Soil type, moisture, source of char, plant species, and many other factors alter effects
- Allow us to ignore other factors
  - This isn't a silver bullet or a fix-all
- Cook, clean, laundry, etc.

Biochar bottom line

- The future is promising
- We are seeing positive responses
  - soil initially
  - physiological
  - over time -> tree aesthetics
- Buyer beware!
- Lots of questions