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Fixed carbon (biochar): enabling a thriving rhizosphere

March 5th, 2019

Santa Maria, CA

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There has been a lot of discussion about “Biochar” lately

The bright prospect of biochar

Biochar is amazing stuff

Can Biochar Help Save the World?

BY PETE DANKO / BIOFUELS, RENEWABLE ENERGY / OCTOBER 15, 2013

Biochar: Black Gold or Just Another Snake Oil Scheme?

BY RACHEL SMOLKER – SEPTEMBER 18, 2013

There’s little basis for claims that biochar could solve our energy, food, and climate woes

website, http://www.newcarboneconomy.info, you can find out about biochar and sign the petition.

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What is Biochar? Biomass + Pyrolysis = Biochar

Biomass + **Pyrolysis** = Biochar

High Heat (300-800 C)
without Oxygen

\+

=

Biochar is the carbon skeleton left over from biomass

Biomass selection, pyrolysis conditions, etc – ALL matter

Soil Carbon – A Key Component of Soil Health

Soil carbon comes in many forms… each plays an important role

Biochar

Labile

- Compost
- Manure
- Nutrient Rich
- Highly degradable
- Short-lived

Humic

- Humus
- Humic / Fulvic Acids
- Complex organic compounds
- Degradable

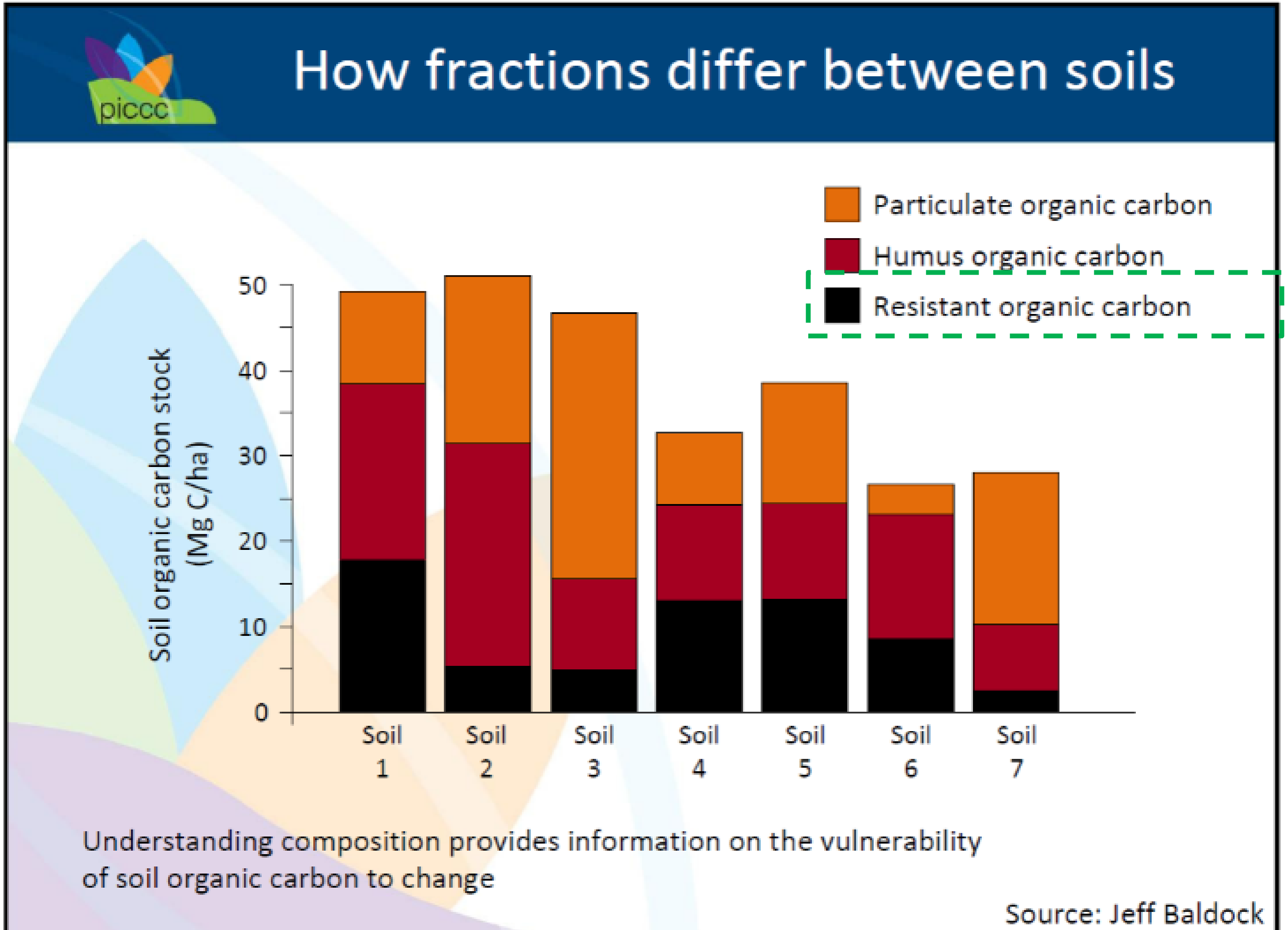
Recalcitrant

- Mostly pyrogenic
- Structural
- Fixed Carbon
- Long Lasting

These three types of carbon can complement each other

Native soils contain all three types of carbon

All three needed in balance for a healthy soil



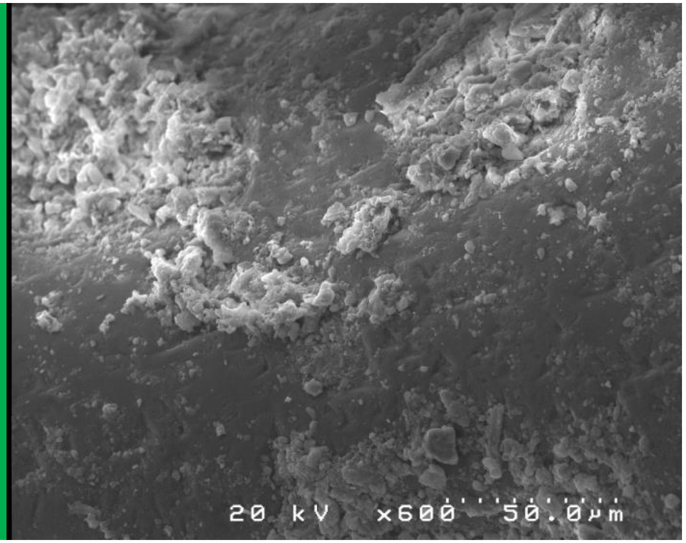
Source: Dr. Jeff Baldock, Research Scientist at Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO)

Environmental structure is the backbone of ecosystems

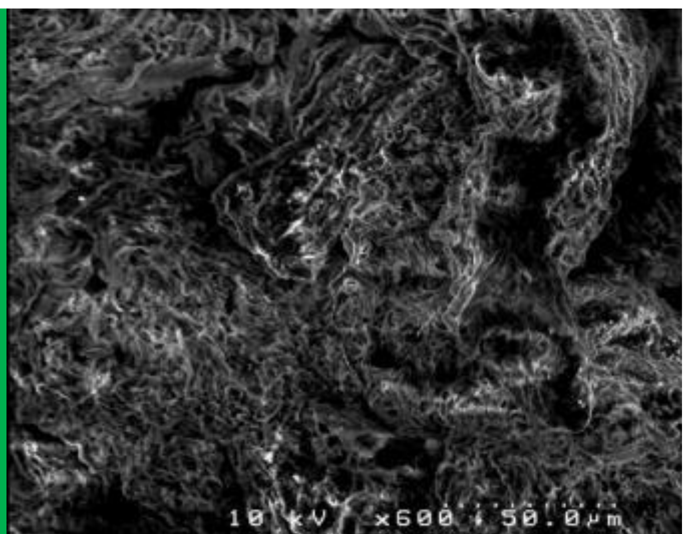
Structure turns nomads into settlers…

Porous Carbon vs. Sand or Peat

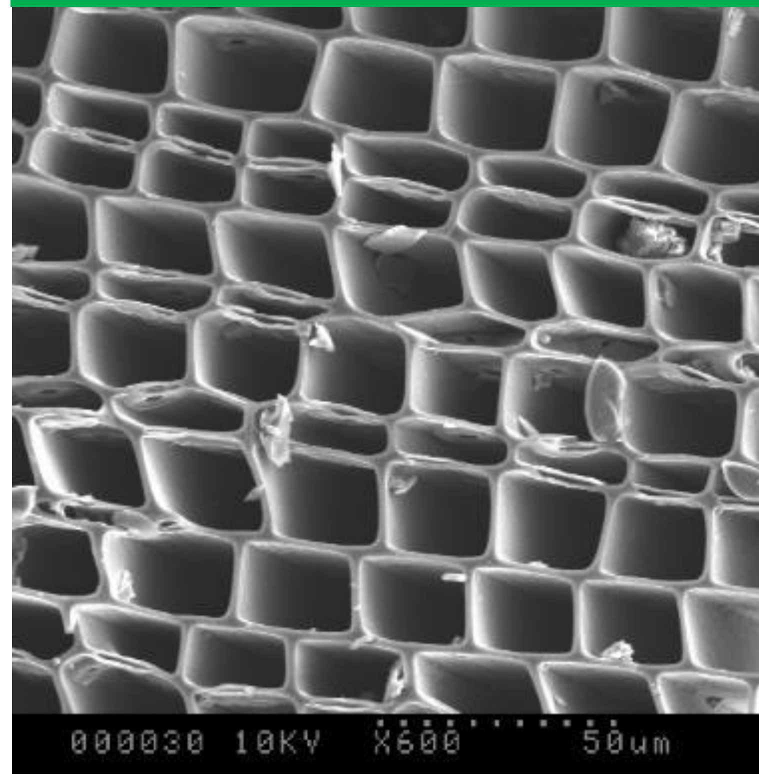
Sand



Peat



Porous Fixed Carbon



Extreme levels of porosity to:

- Hold water
- Exchange nutrients
- Provide a microbial habitat

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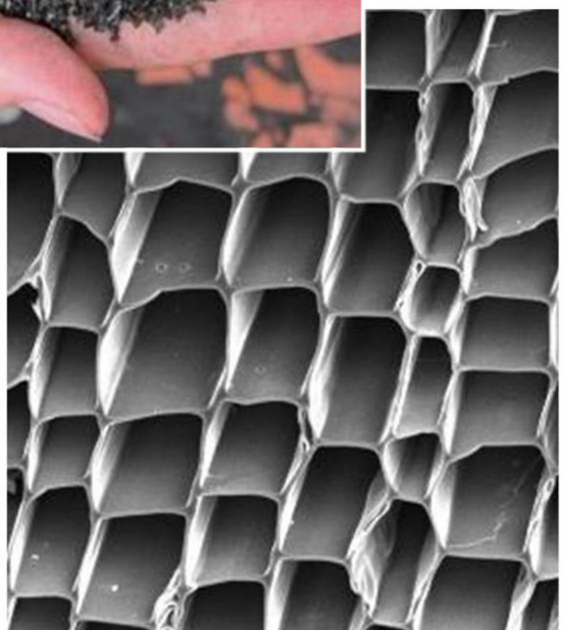
Recalcitrant, porous carbon (biochar) has the potential to address a range of soil issues



Biochar structure under a scanning electron microscope

1. **Adsorptive / Desorptive**
   - Holds water
   - Retains nutrients
2. **Porous**
   - Anchors micro-roots
   - Promotes microbial growth as "habitat"
3. **Structure**
   - Pathway for water and oxygen
   - Aeration in clay soils
   - Structure in sandy soils
4. **Complementary**
   - Complements with nutrition, humic, compost, microbes

Cool Terra® contains essential ingredients for microbial life thriving in soil

Neutral pH	Balance of moisture and air space	Numerous attachment sites (surface area)
Strong cell wall structure	Ion Exchange Capacity	Pore size distribution fit for most microbes

Field studies show positive microbial growth in soil using ag practices

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Cornell University study highlights high-definition electron pathway potential in pyrogenic carbon

Quotes from Study Authors

"Microorganisms need electrons for everything they do. If they consume nutrients or spew out methane or expel carbon dioxide – for any living, biological process – they need electrons,"

". . .electrons convey through soil via carbon (…) amending the soil with **pyrogenic carbon (…) brings high definition to the electron network** In turn, the electrons spur conductive networks and growth

Can potentially help microbes perform basic natural functions

Tianran Sun et al. Rapid electron transfer by the carbon matrix in natural pyrogenic carbon, Nature Communications (2017). DOI: 10.1038/ncomms14873

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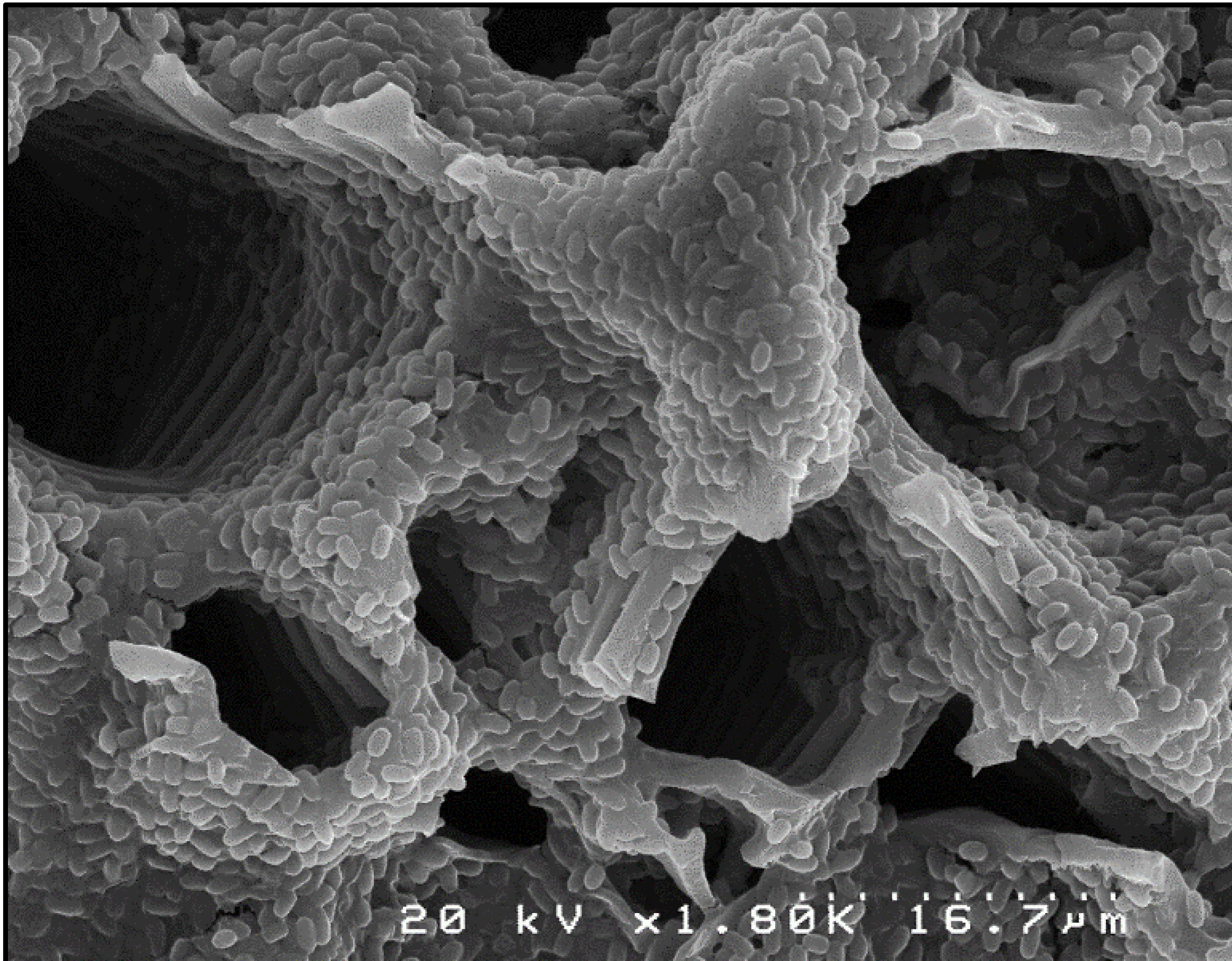
Soil microbes inhabiting Cool Terra® surface and pores



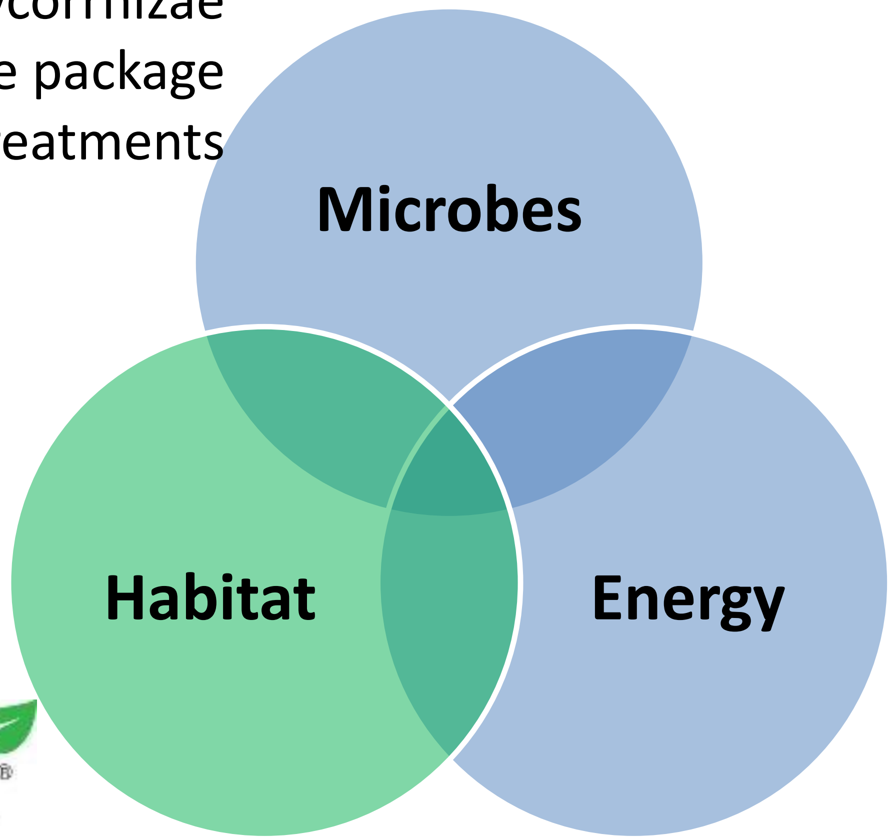
Luxury Condos for microbes

Photo is of biocarbon and Rhodospirillum rubrum at 16 microns

Multi-dimensional ecosystem vital for thriving soil biome

Each part can have impact, but the full system can be very powerful for soil health

- Mycorrhizae
- Beneficial microbe package
- Microbial seed treatments



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- Compost
- Humic
- Biostimulants

Synergistic impact likely possible with combinations

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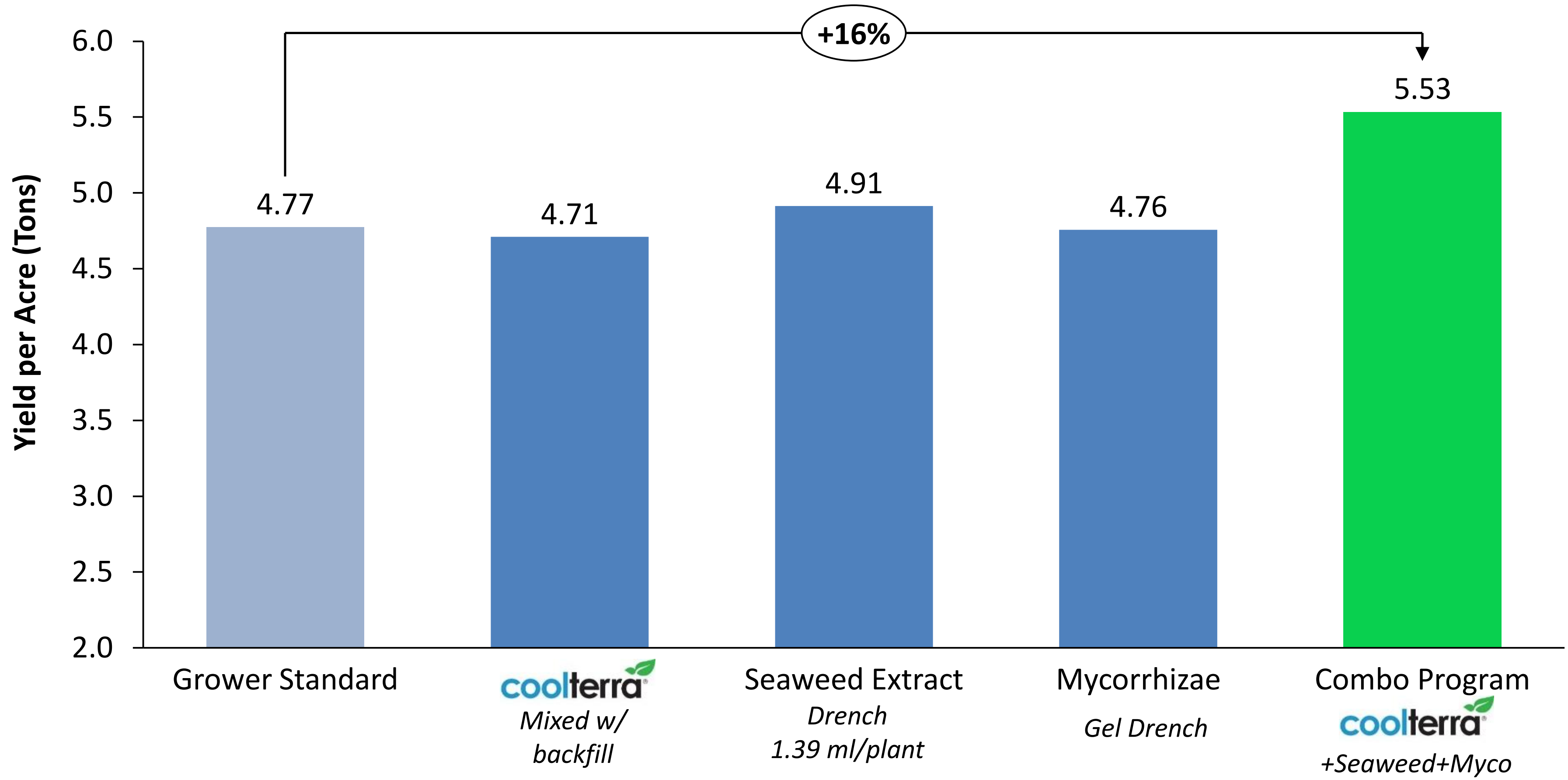
Established Chardonnay, Zabala Vineyards, Soleadad CA

Jason Melvin (Vineyard Mgr) and Mark Mahady (Researcher)

Established vines (~7 years old), Stony and Coarse Textured Soil (Loamy Sand)

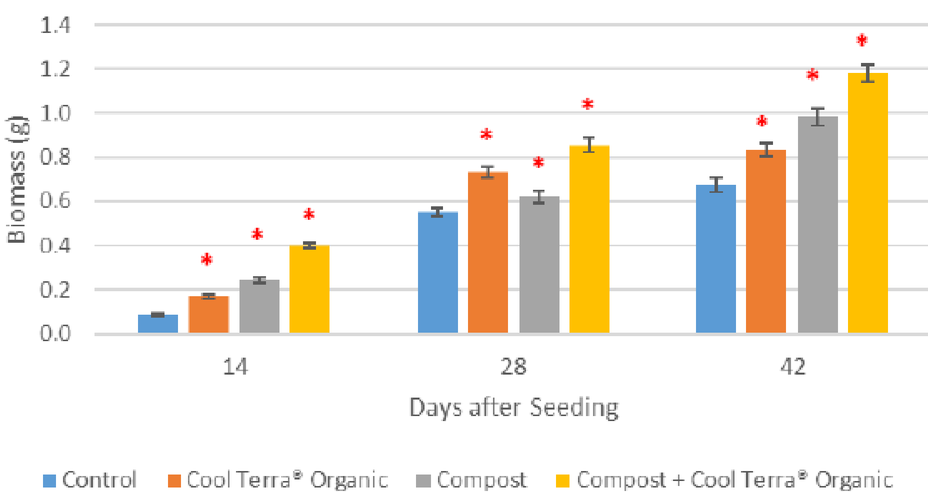


6 reps per treatment, 5 vines per rep. Existing block of chardonnay grapes (C-11 chardonnay 4 on 101/14 rootstock) planted in 2011-2012, on 8' rows and 4' spacing (1361 vines per acre). For CT treatments soil around base of vine was removed in 28"x28"x4" swath and blended at 5% v/v Cool Terra® then returned to the soil. Drench treatments were mixed in 1000 ml of water and slowly poured into a created soil crater next to the plant underneath the drop emitter. Seaweed Extract is Ocean Organics Drench GN8. Myco is RTI Program Plus Mykos Gel which includes mycorrhizae fungi and wetting agent.

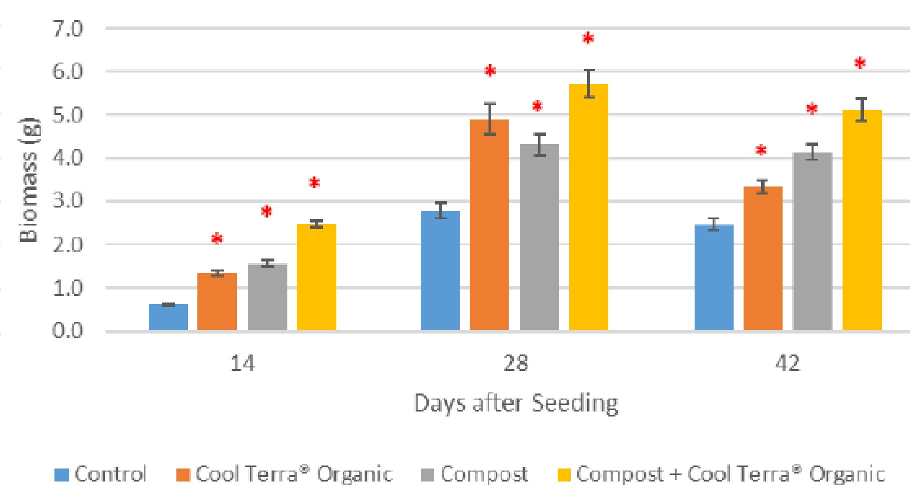
Tall Fescue Growth Trial to Compare with Compost

Tall Fescue Greenhouse Trials indicate synergy when used with Compost

Wet Shoot Biomass

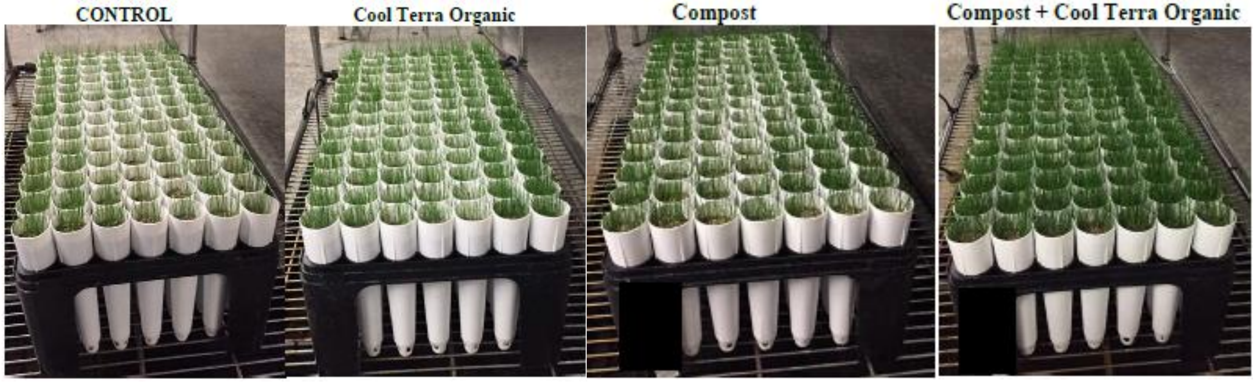


Wet Root Biomass



Trial Images -- 14DAS

CONTROL | Cool Terra Organic | Compost | Compost + Cool Terra Organic



Trial Images -- 28DAS

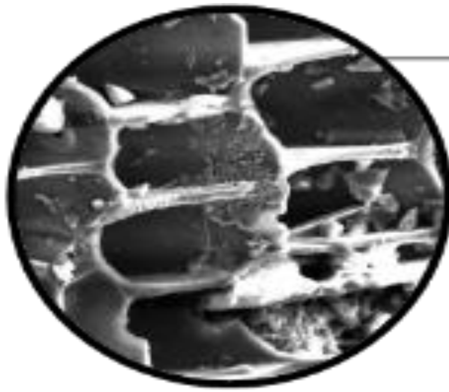
Compost

Compost + Cool Terra® Organic

* Statistically signifiant at the 5% level

Internal CP Study, Location: Camarillo, CA. 98 single container reps per treatment. For each timepoint 1/3 of reps were gathered and measured.
Growth substrate : calcium bentonite clay. Cool Terra Organic and Compost were both applied at 1CY/A - Vermicompost

But. . .Raw Biochar Has Historically Proven Inconsistent



Biochar as co-produced with hyrdrocarbons

Raw Biochar

Key Physical, Chemical Properties. . .

High: ↑ pH levels ↑ Phytotoxic Concentration

Low: ↓ Pore Capacity ↓ Process (pyrolysis) Control & Expertise

. . .Can Lead to Inconsistent Results

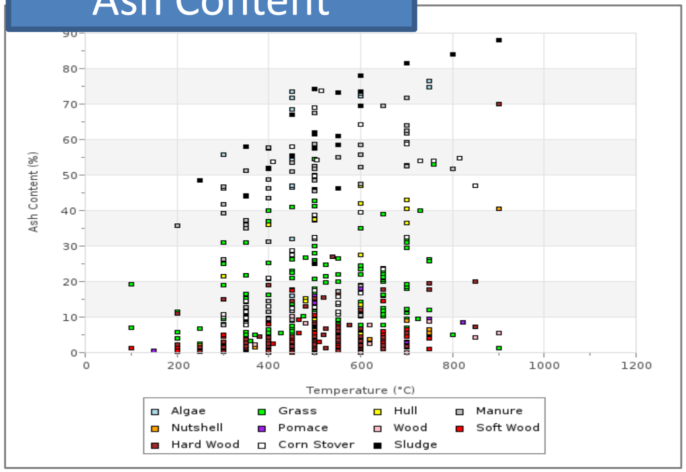
↓ Elements of Soil Health ↓ Ag Production

3rd Party Research
- Rajkovich, S. et al. Biol. Fert. Soils 48, 271–284 (2012).
- Spokas, K, et al. J. Environ Qual., Jul-Aug: 973-89 (2012)
- Gaskan, J, et al. Am Soc Agron, Vol 102 #2, p. 623-33 ('09)
- Major, J, et al. Plant & Soil, Vol 333, Issue 1, p. 117-28 ('10)

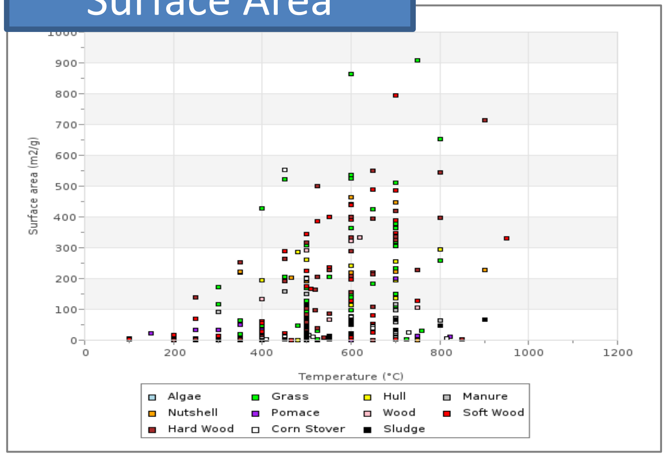
Historically, biochar has been inconsistent, due to lack of understanding of key properties and production process to optimize performance

Snapshot Plots from UC Davis Biochar Database

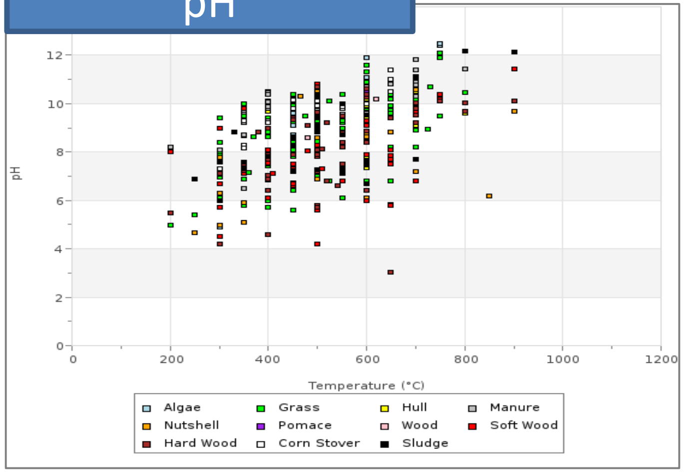
Ash Content



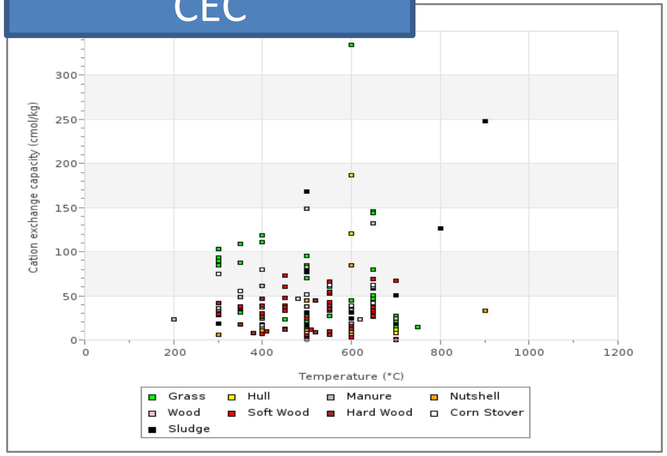
Surface Area



pH



CEC



Extreme variability of raw biochar prevents broader adoption

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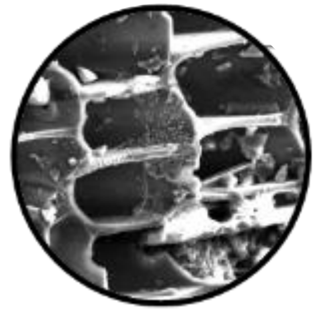
Our Differentiator: Engineered Biocarbon™ Technology

Pyrolysis expertise and proprietary post treatment designed to maximize consistency & effectiveness

Biomass
(e.g., Nutshell, Pine)

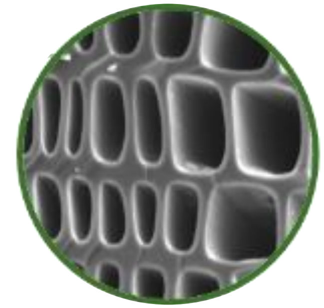
Pyrolysis



Raw Biochar

Post Pyrolysis Treatment

Proprietary



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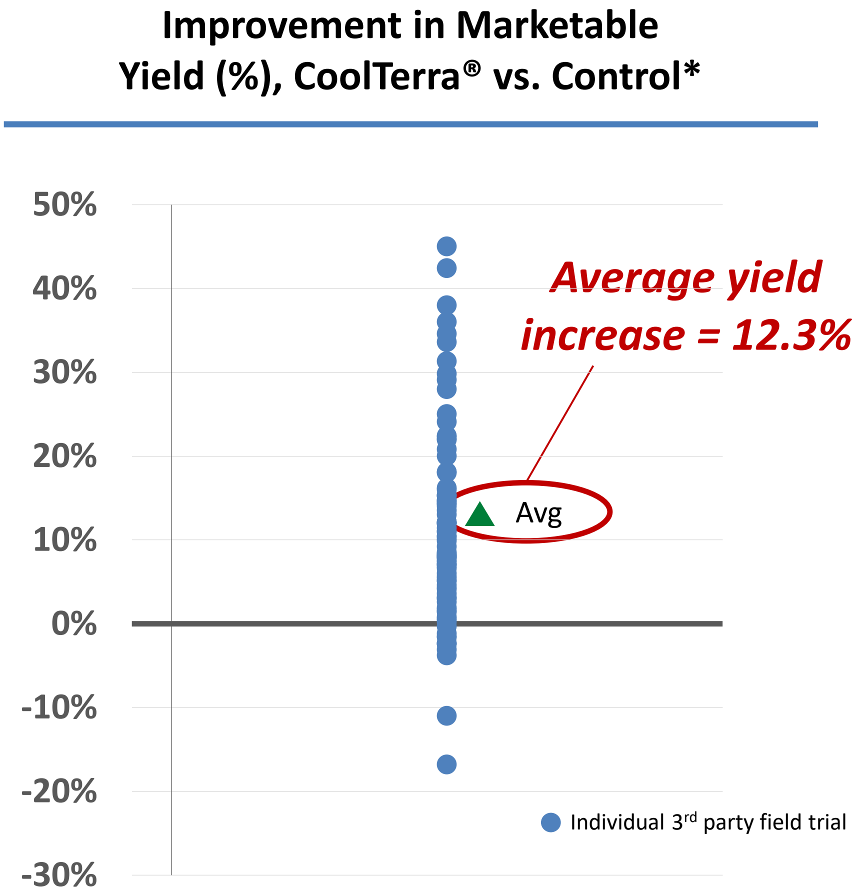
- **Modify surface chemistry** – Optimizing pH, ion exchange and hydrophilicity
- **Minimize Detrimental Compounds**– Through feedstock selection, controlled pyrolysis, and post-treatment
- **Maximize Capacity –** Improves pore accessibility for maximum input holding capacity
- **Formulate for application** – Consistent, low-dust, flowable, for ease of shipping, storing, and applying

Results from 120+ <u>independent</u> field trials over three seasons have shown consistent crop yield increases



Trial Result Highlights

Results vs. Grower Standard *(Typical levels of water and fertilizer)*			
Crop, Location	**Trial Researcher**	**Yield**	**ROI**
Strawberry, Oxnard CA	David Holden Research	+31%	+20x
Lettuce, Salinas CA	Pacific Ag Rsrch	+18%	+12x
Carrot, Merced CA	Helena R&D	+11%	+15x
Tomato, Naples FL	Univ of Florida	+9%	+10x
Radish, Tifton GA	Univ of Georgia	+60%	+20x

Trials have shown average yield increases of ~12% with greater than 5:1 grower ROI

**Includes results from 120+ field trials that produced data on marketable yield for treated vs. grower standard control in 2016, 2017, 2018*

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**Lettuce (Spyglass Head Lettuce) ; Spinach (Admiral); Carrot (Danvers); Tomato (Proprietary), Corn (DKC 60-88 VT2PRIB)*

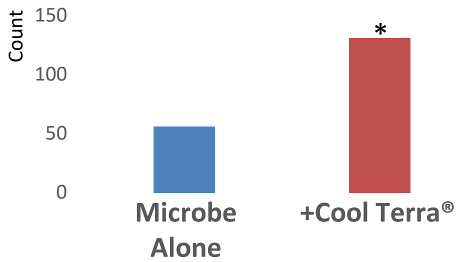
Evaluations on microbial life

Lab **Greenhouse** **Field**

Cool Terra® improving microbial response in legume crop

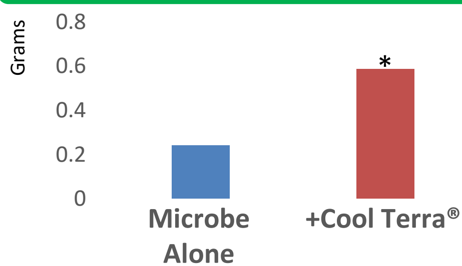
Significant impact over 10 weeks with Brady rhizobium inoculant when Cool Terra® added

Root Nodulation



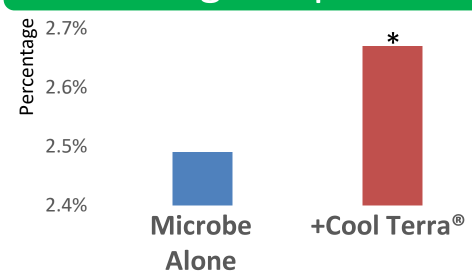
>2x impact

Root Biomass



>2x impact

Nitrogen Uptake



~10% impact

Microbe Alone | coolterra®

Impact on Root Nodulation

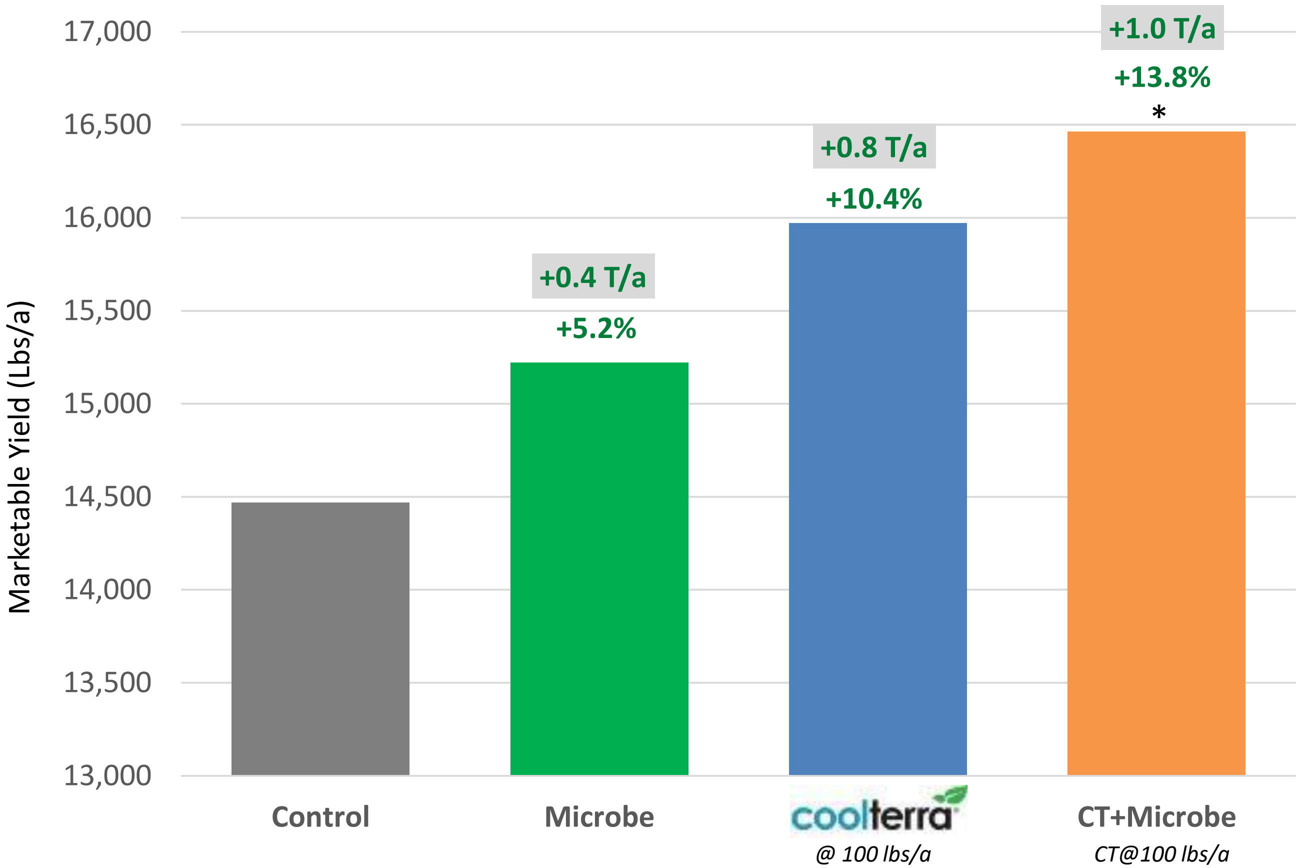
Impact on Root Development

Cool Terra® (CF-12) added at 10% v/v to a soilless peat mix containing soybean seeds treated with a commercial Brady rhizobia product, N-Dure™ manufactured by Verdesian. Control is same soilless peat mix with 10% perlite addition and same N-Dure™ treatment as Cool Terra treatment. 9 reps per treatment, results statistically significant at 99% confidence level

Cool Planet Internal Research

Field Trial with Microbes: Lettuce, Steve West (RD4AG), Yuma, AZ

Planted: March 2nd, 2017 Harvested: April 14th, 2017



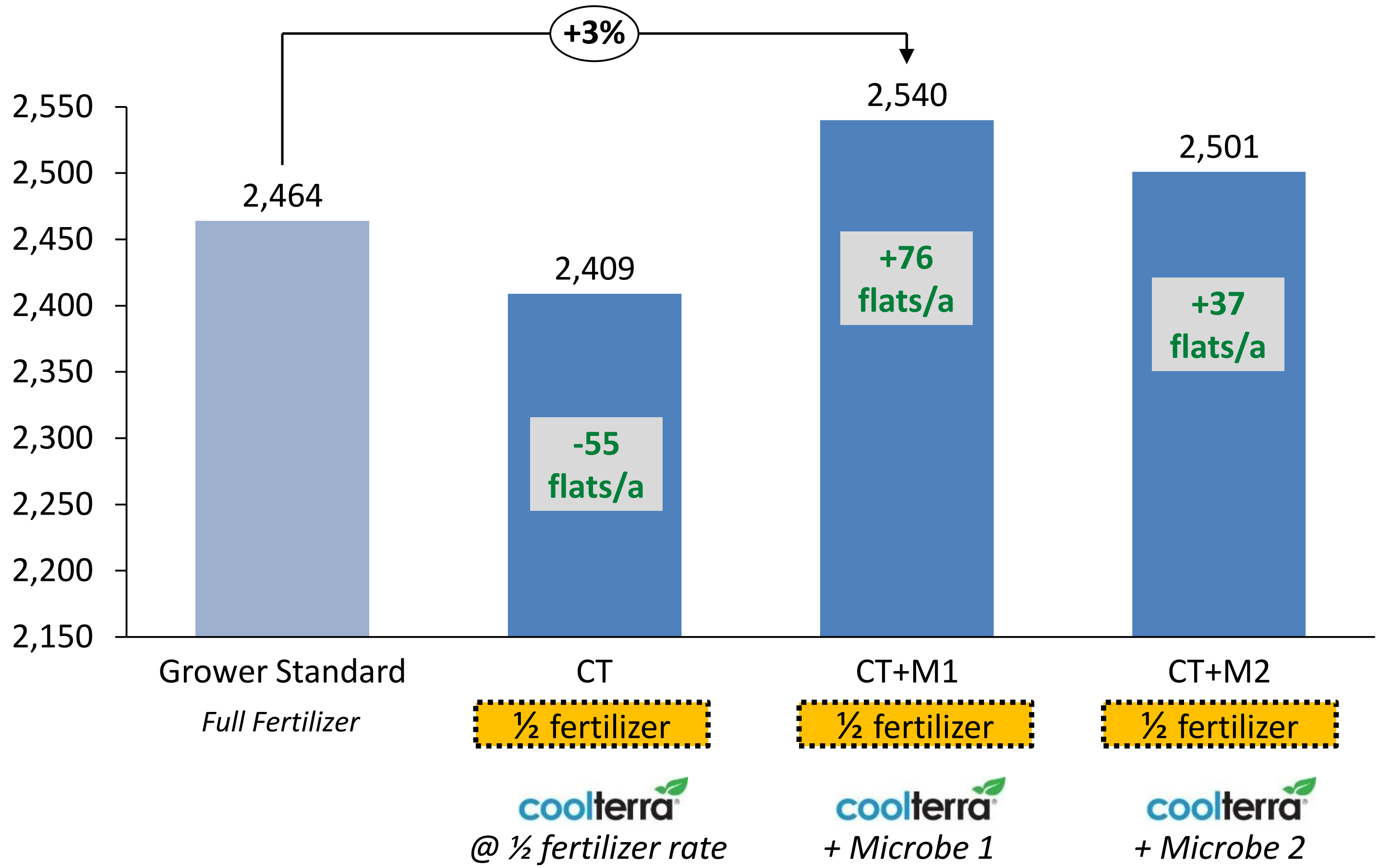
	Control	Microbe	Coolterra	CT+Microbe
Revenue Per Acre ($K) *Assumes ~$1,200 / Ton ($0.60/lb)*	$8.7	$9.1	$9.6	$9.9
Difference vs. check ($)		+$451	+$902	+$1,198
Return on Investment**		N/A	+12.2x	N/A

* Denotes Statistical Significance (P<0.05) vs. Control

Cool Terra® price $0.70/lb, Microbe partner under NDA. Lettuce price assumed $0.60/lb.

Strawberry: Commercial Grower, Holden Research & Consulting

Oxnard, CA. 30 picks between 12/7/2017 and 3/26/2018



	Grower Standard	CT	CT+M1	CT+M2
Fertilizer 18-8-13 *(lbs/a)*	500	250	250	250
Cool Terra® *(lbs/a)*	0	250	250	250
Microbial Addition	No	No	Yes	Yes

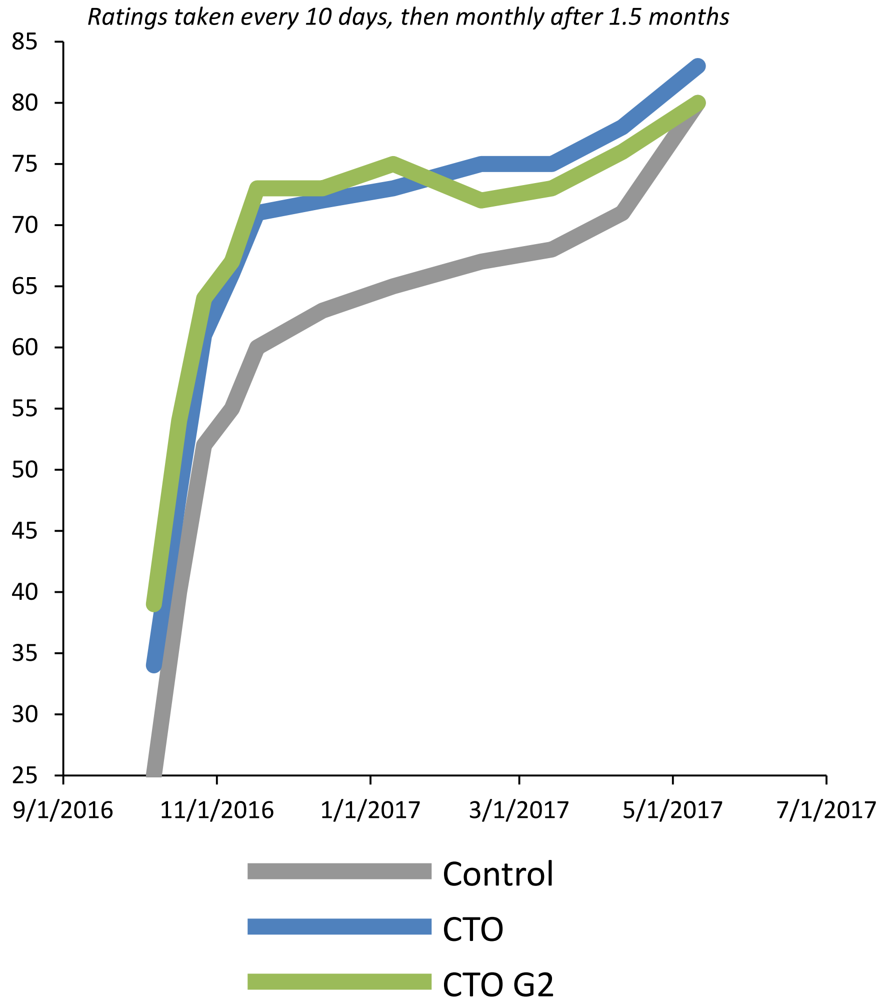
Variety: Fortuna. RCB Design, 6 reps per treatment, each rep 15’ long x 6’ wide. Blended materials knifed in on 8/22/17 under plant line, apx 6-9 inches deep.

Tall Fescue Trial: Grady Miller, Turfgrass Mgmt Faculty

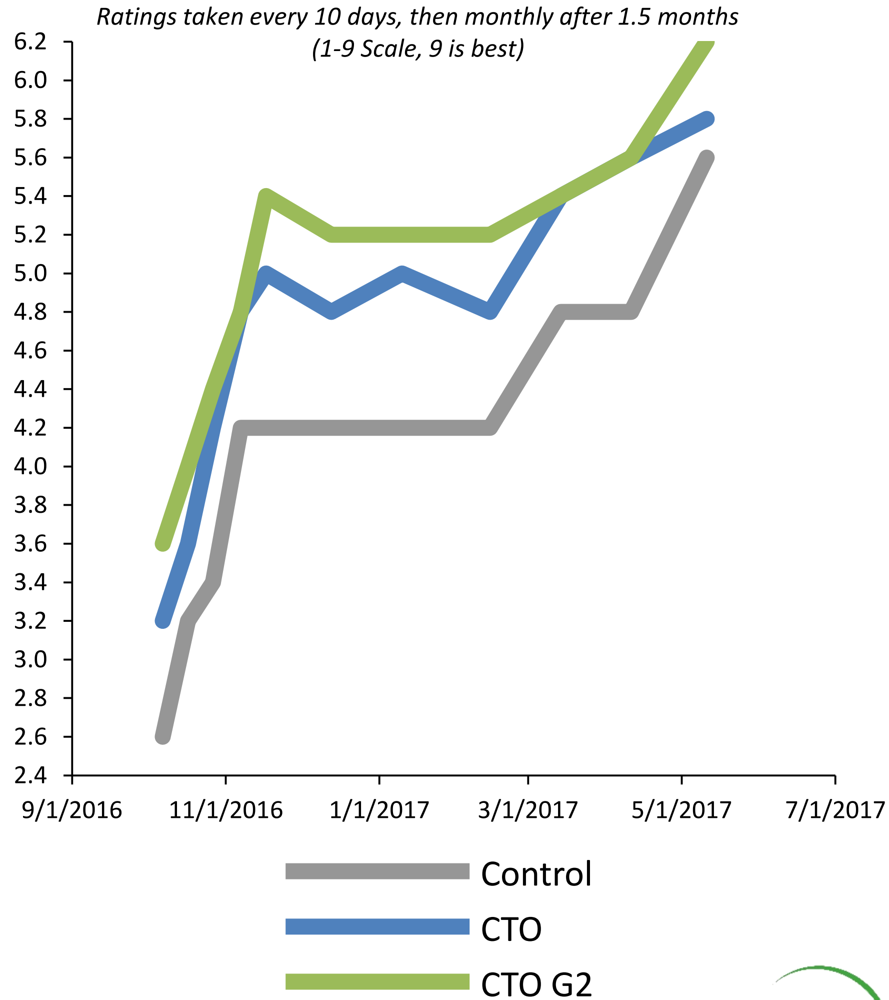
NC STATE UNIVERSITY

Trial Start: Sep 2016 Trial End: May 2017 Location: Raleigh NC

% Coverage



Quality (1-9)



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Aerified, raked clean, broadcast biochar by hand over weak established stand, dragged/raked in, seeded. CTO Rate was 1 cf/1000sf in fall and topdress 1 cf/1000sf on 3/28/17 CTO G2 Rate was 2 cf/1000sf in fall. Seeding Rate 6 lbs/M. Randomized Complete Block, 5 reps / trtm. Plots 24 ft^2/plot; Soil: Cecil , moderate drainage; Early spring fertilizer application on 3/3/2017: 21-0-0 at 0.5 lbs N/M. *LSD for trial average is at 5%*

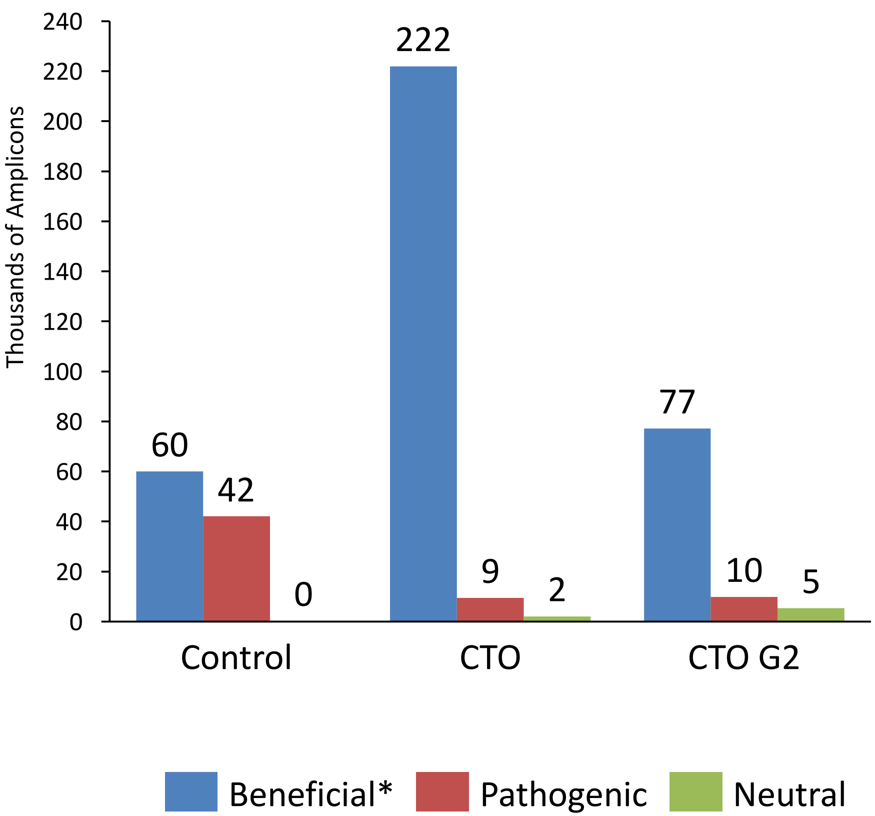
Tall Fescue Trial: Grady Miller, Turfgrass Mgmt Faculty

NC STATE UNIVERSITY

Trial Start: Sep 2016 Trial End: May 2017 Location: Raleigh NC

Fungal Counts

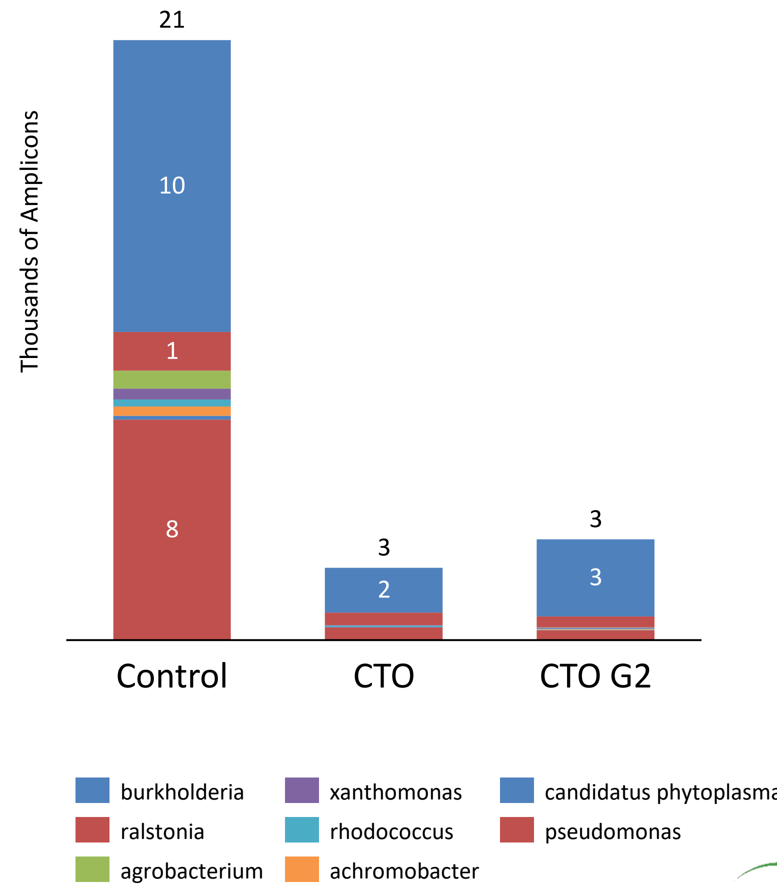
Microbial soil sample taken at trial end; DNA Sequencing performed by MR DNA, Shallowater, TX



*Beneficial = Sum of Symbionts, Saprophytes and Mycorrhizae

Bacterial Pathogens

Microbial soil sample taken at trial end; DNA Sequencing performed by MR DNA, Shallowater, TX



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Thank You For Your Time!

Please see us afterwards with questions