SARE Biochar Trial at BV2

Improving Soil Health with Biochar and Compost Applications in North Coast Vineyards

TREASURY WINE ESTATES

Western SARE Biochar Trial

Improving Soil health with Biochar and Compost Applications in North Coast Vineyards

MONTANA STATE UNIVERSITY — **Subaward Service Agreement** — **MSU ID G351-21-W8613**

Pass-Through Entity (PTE)		**Subrecipient**
Name Address	Montana State University Office of Sponsored Programs PO Box 172470 Bozeman, MT 59717-2470	Name Treasury Wine Estates Americas Co Address 555 Gateway Dr Napa, CA 94558 Duns
PTE Principal Investigator: Clayton Marlow		Principal Investigator: Michael Sipiora
PTE Awarding Agency: USDA National Institute of Food and Agriculture		PTE Awarding Agency ID: 2020-38640-31523-WS1FR
PTE CFDA 10.215 Sustainable Agriculture Research and Education		This subaward is subject to OMB Uniform Guidance PTE FAIN: 2020-38640-31523
Subaward Title: Improving soil health with biochar and compost application in North Coast Vineyards		
Subaward Period of Performance Start **06/01/2021** End **05/31/2024**	Authorized Amount **24,583.00**	**Subaward ID: G351-21-W8613** 1. Cost Sharing is Not Required 2. This award is a Cost Reimbursable agreement 3. Project Reporting is Required (Attachment 4A)

Treatments:

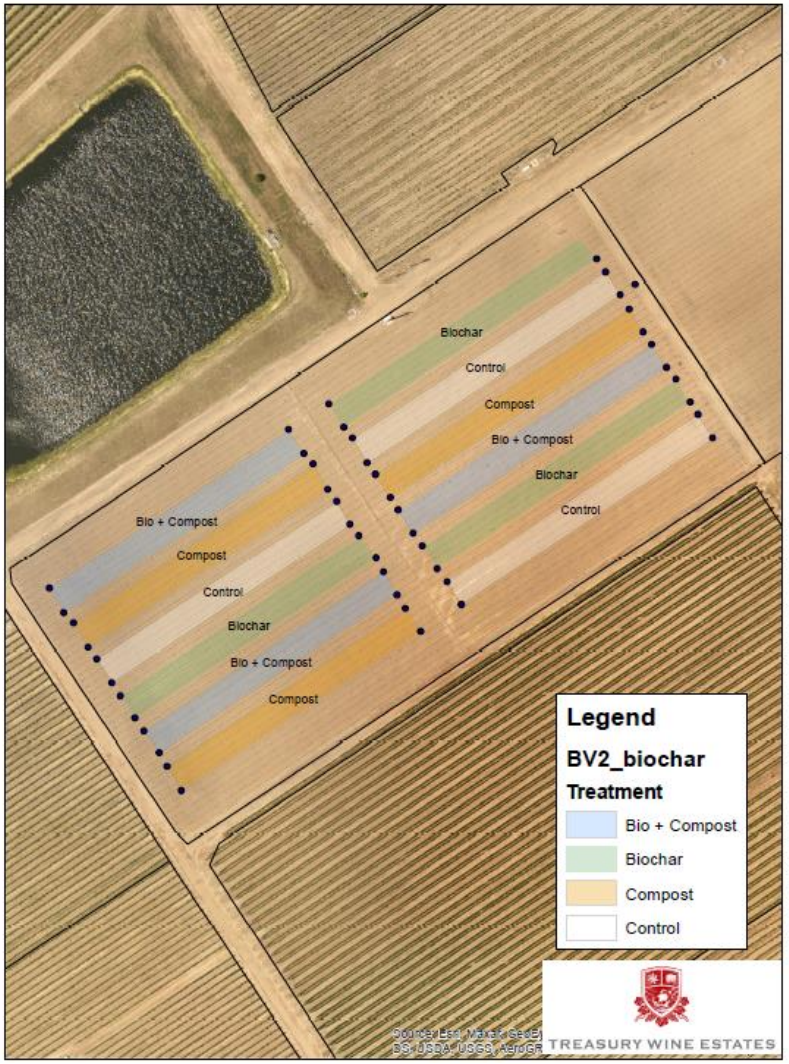
1. BIOCHAR broadcasted at a rate of 10 tons/acre

2. COMPOST broadcasted at a rate of 20 tons/acre

3. BIOCHAR broadcasted at a rate of 10 tons/acre + COMPOST broadcasted at a rate of 20 tons/acre

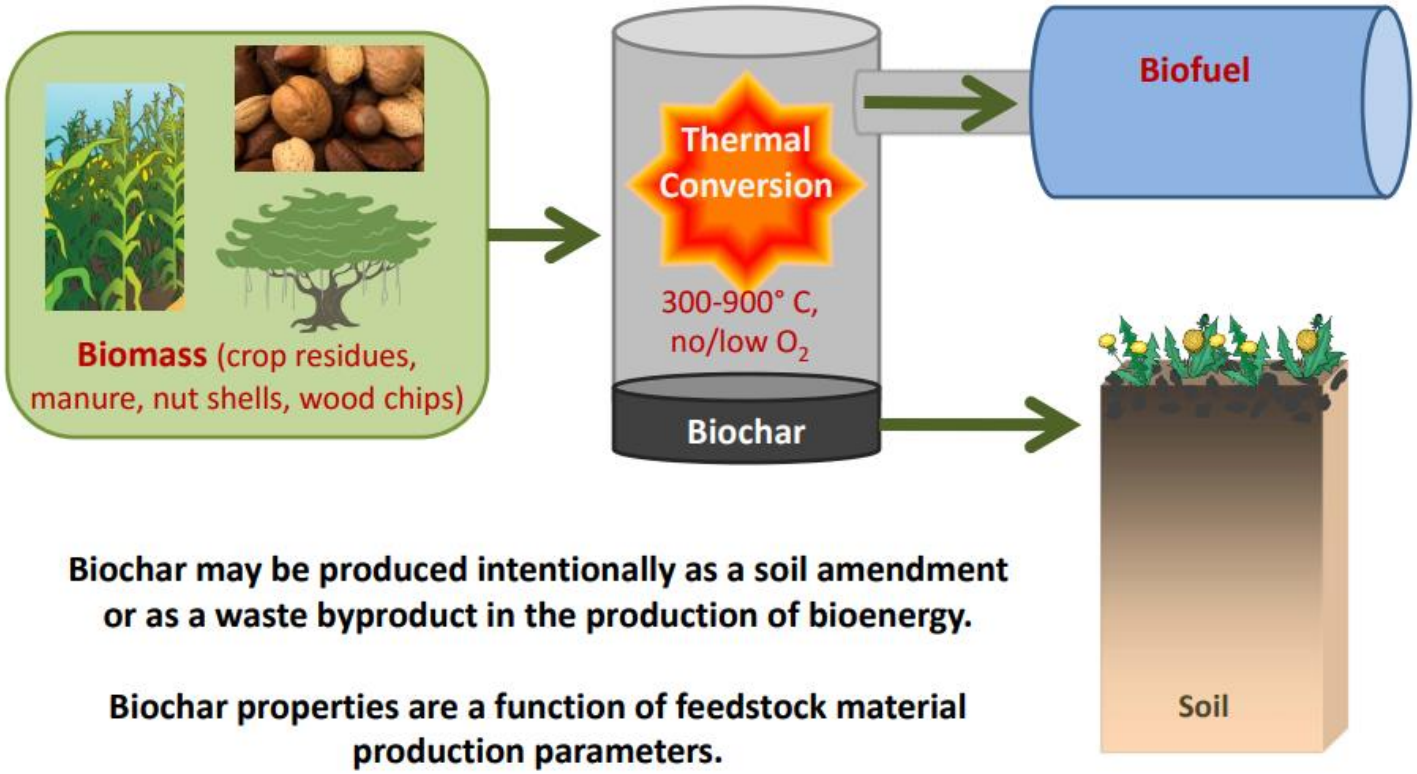
4. Control with no amendments added.

Beaulieu Vineyard 2 (Biochar Trial)



What is Biochar?

Biochar is charcoal created from biomass, and differs from charcoal only in the sense that its primary use is not for fuel. Typically used as a soil amendment.



Biochar may be produced intentionally as a soil amendment or as a waste byproduct in the production of bioenergy.

Biochar properties are a function of feedstock material production parameters.

Sanjai J. Parikk, UCD

BIOCHAR PRODUCTION AT GAMBLE RANCH

BIOCHAR

Pacific Biochar Low Ash

	Biochar		Biochar Dry Wt	
Bulk Density	19.1	lbs/cu.ft	6.1	lb/cu ft
Moisture	67.8	%	0	%
Organic Matter	-	%		
Carbon	27.7	%	86.2	%
Hydrogen	0.7	%	2.1	%
Nitrogen	0.2	%	0.6	%
Oxygen	1.6	%	5.1	%
Ash	1.9	%	6	%
C:N Ratio	139		144	

COMPOST

Recology Organic Compost from Vacaville (OMRI certified)

	Compost		Compost dry wt	
Bulk Density	37	lbs/cu.ft	24	lbs/cu.ft
Moisture	36.8	%	0	%
Organic Matter	32.7	%	51.5	%
Carbon	17.0	%	26.0	%
Hydrogen	-	%		
Nitrogen	1.1	%		
Oxygen	-	%		
Ash	30.7	%	48.4	%
C:N Ratio	15.3		15.3	

Biochar Delivery and Application in 2021

Aspect of Vineyard plots after Biochar and Compost applications

BIOCHAR AND COMPOST APPLICATION by the Numbers

	Units	Biochar Application	Compost Application	Compost + Biochar
Bulk Density	lbs/cu ft	19.1	37	
Wt. Amend (lbs per yd)	lbs/cu yd	516	999	
Application Rates	cu yd/ row	5.5	5.5	
App Rate (cu yd./acre)	cu yd/acre	39.61	39.61	
App Rate (#/acre)	lbs / acre	20,428	39,573	60,002
App Rate (tons/acre)	tons / acre	10.21	19.79	30.00
Carbon applied	%	27.7	17	
tons per acre	tons / acre	2.83	3.36	6.19
lbs per acre	lbs /acre	5,659	6,727	12,386
Expected C increase per acre		0.28%	0.34%	0.62%
C:N Ratio		139	15	26
Nutrients Applied				
N	lbs/acre	41	435	476
P	lbs/acre	2	79	79
P205	lbs/acre	5	178	178
K	lbs/acre	9	257	257
K20	lbs/acre	11	309	309

MOVING THE NEEDLE
How much material required to improve C levels in soil.

- **ACRE FURROW SLICE**
- **The weight of an acre (43,560 sq. ft) of soil to a depth of 6.7 inches.**
- **Total cubic feet per acre would be 23,934.**
- **With a soil bulk density of 1.33 g/cu cm, the weight of a cubic foot equal 82.99 pounds.**
- **The weight of an acre furrow-slice then is approximately 2,000,000 pounds or 1000 tons.**

- CARBON APPLIED;
  - BIOCHAR: 2.83 TPA C / 1000 TPA = 0.28%
  - COMPOST: 3.36 TPA C / 1000 TPA = 0.34%
  - BIO + Compost: 6.19 TPA C / 1000 TPA = 0.62%

MOVING THE NEEDLE

How large of an investment required to improve C levels in soil.

BIOCHAR AND COMPOST APPLICATION COSTS

	Cost ($/ton)	Application Rate (tons/acre)	Materials ($/acre)	Labor Cost ($/acre)	Total Cost ($/acre)
Biochar	325.75	10.21	3,325.92	81.03	3,406.94
Compost	51.84	19.79	1,025.98	105.41	1,131.38
Bio + Compost	145.06	30.00	4,351.89	186.43	4,538.33

BIOCHAR AND COMPOST BREAK EVEN POINT

	Cost Amendment ($)	Price Cabernet Sauvignon ($/ton)*	Yield increase (tons) to offset investment
Biochar	3,406.94	6,261.00	0.54
Compost	1,131.38	6,261.00	0.18
Bio + Compost	4,538.33	6,261.00	0.72

**** District average price for 2020 (Napa Crop Report)***

TWE

Soil Sampling and Testing

Oregon State University
Soil Health Laboratory
soil.lab@oregonstate.edu 541-737-2187
Crop and Soil Science Department 3079 Ag-Life Sciences Bldg Corvallis, OR 97331
Soil Health Analysis Report

Name:	Michael Sipiora
Organization:	Treasury Wine Estates
Contact for results:	michael.sipiora@tweglobal.com
Date submitted:	5/12/2022
Date delivered:	6/28/2022
Group number:	222234Q

Oregon State University

Method Descriptions

Moisture	Gravimetric moisture as sample is received. All other data reported on a dry matter basis
Texture	Determined with Hydrometer method after cementing and flocculating agents removed
Water Stable Aggregates	Percentage of 0.25 - 2.00 mm aggregates that stay on a sieve after a simulated 5 minute rain using the Cornell Sprinkle Infiltrometer
CN	Dry combustion and direct measurement of total nutrients with Elementar Macro Cube
OM	Organic matter calculated using total organic carbon * 2 as per review by Pribyl, 2010 in Geoderma
Active Carbon	Readily oxidizable carbon measured by potassium permanganate reduction.
CO2 Respiration	CO2 evolution measured after 24 hour and 96 hour incubation with soil wetted to 50% water filled pore space incubated at 23C
Potentially Mineralizable Nitrogen	NO3-N measured at time 0 using 2M KCl extraction followed by a 28 day incubation at 50% water filled pore space at 23C. NO3-N measured again with 2M KCl extraction at day 28 to calculate the rate of nitrogen mineralization.
pH EC	Measured in 1:1 soil:water ratio on Hanna HI5522 benchtop meter
P, K, Ca, Mg	Extracted with Mehlich 3 solution, measured on Agilent 5110 ICP-OES
CEC	Sum of bases estimation of CEC
BQL	Below quantifiable limits

SOIL HEALTH RESULTS

TOTAL CARBON (%)				
Treatments	**2021**	**2022**	**2023**	**DELTA ('21-'23)**
Biochar + Compost	1.10	1.34	1.59	0.50
Biochar	1.16	1.15	1.23	0.07
Compost	1.27	1.14	1.09	-0.18
Control	1.18	1.07	0.90	-0.28
Average	**1.18**	**1.18**	**1.20**	**0.03**

- Total C increased with BIO + Compost
- Total C decreased in Compost and Control Treatment plots

ORGANIC MATTER (%)				
Treatments	**2021**	**2022**	**2023**	**DELTA**
Biochar + Compost	2.19	2.69	3.19	0.99
Biochar	2.32	2.31	2.46	0.14
Compost	2.55	2.29	2.20	-0.35
Control	2.35	2.13	1.80	-0.55
Average	**2.35**	**2.35**	**2.41**	**0.06**

- Organic Matter increased with BIO + Compost treatment
- OM stayed relatively same with biochar treatment
- OM decreased in Compost and Control Treatment plots

SOIL HEALTH RESULTS

TOTAL NITROGEN (%)				
Treatments	**2021**	**2022**	**2023**	**DELTA**
Biochar + Compost	0.12	0.11	0.12	-0.01
Biochar	0.11	0.10	0.10	-0.01
Compost	0.13	0.11	0.11	-0.02
None	0.11	0.10	0.08	-0.03
Average	**0.12**	**0.11**	**0.10**	**-0.02**

- Total N was significantly increased by application of compost
- Differences between treatments was very small

C:N RATIO				
Treatments	**2021**	**2022**	**2023**	**DELTA**
Biochar + Compost	9.0	11.7	13.6	4.6
Biochar	10.7	11.1	11.9	1.2
Compost	9.7	10.1	10.2	0.6
None	10.7	10.4	10.8	0.1
Average	**10.0**	**10.8**	**11.6**	**1.6**

- The ratio of C:N increased with biochar applications
- Total C decreased in Compost and Control Treatment plots

SOIL HEALTH RESULTS

ACTIVE CARBON (ppm)				
Treatments	**2021**	**2022**	**2023**	**DELTA**
Biochar + Compost	244	213	473	229
Biochar	220	196	426	206
Compost	214	217	430	216
None	222	211	440	218
Average	**225**	**209**	**442**	**217**

- Active C was not influence by any of the treatments
- The levels of active C varied seasonally

CO_2_Respiration 24H (ug/g/day)				
Treatments	**2021**	**2022**	**2023**	**DELTA**
Biochar + Compost	77	37	54	-23
Biochar	94	35	44	-50
Compost	95	46	37	-57
None	95	47	36	-59
Average	**90**	**41**	**43**	**-47**

- Soil CO2 respiration rates have not been impacted by treatmentd
- Rates vary with season

SOIL HEALTH RESULTS

Water Stable Aggregates (%)				
Treatments	**2021**	**2022**	**2023**	**DELTA**
Biochar + Compost	33	37	32	-1
Biochar	44	43	30	-14
Compost	37	30	18	-20
None	39	29	22	-17
Average	**38**	**35**	**25**	**-13**

- Water stable aggregation significantly improved in 3rd year with biochar application

Potential Mineralizable N (mg N/kg/day)				
Treatments	**2021**	**2022**	**2023**	**DELTA**
Biochar + Compost	0.33	0.37	0.57	0.24
Biochar	0.24	0.27	0.41	0.18
Compost	0.40	0.37	0.44	0.04
None	0.37	0.19	0.40	0.03
Average	**0.33**	**0.30**	**0.46**	**0.12**

- Potentially mineralizable N increase by compost application year after being applied

VINE Nutrition

Bloom Leaf Blade Analysis 2022

TREATMENT	N	P	K	Mg	Ca	S	Na	Zn	Cu	B	Al	Fe	Mn
	% dry weight							ppm dry weight					
Biochar + Compost	3.62	0.26	1.22	0.48	2.50	0.21	0.01	90	9	58	108	109	83
Biochar	3.68	0.27	1.16	0.50	2.70	0.22	0.01	86	9	57	114	112	87
Compost	3.62	0.26	1.19	0.45	2.32	0.25	0.02	133	9	70	131	109	79
None	3.67	0.27	1.16	0.47	2.50	0.24	0.02	128	9	72	125	105	75
Biochar	*ns*	*ns*	*ns*	*ns*	*ns*	***0.05***	***0.05***	***0.05***	*ns*	*ns*	***0.05***	*ns*	*ns*
Compost	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Biochar x Compost	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Rep	*ns*	*ns*	***0.05***	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

Bloom Leaf Blade Analysis 2023

TREATMENT	N	P	K	Mg	Ca	S	Na	Zn	Cu	B	Al	Fe	Mn
	% dry weight							ppm dry weight					
Biochar + Compost	3.35	0.23	1.04	0.29	1.70	0.44	0.02	267	10	45	168	140	69
Biochar	3.45	0.24	0.96	0.28	1.62	0.42	0.02	261	9	44	158	135	66
Compost	3.28	0.21	0.92	0.43	1.57	0.40	0.02	257	8	40	146	119	60
None	3.29	0.22	0.95	0.30	1.77	0.43	0.02	266	8	42	153	125	67
Biochar	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Compost	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Biochar x Compost	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Rep	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

VINE Nutrition

Bloom Leaf Blade Analysis 2022													
TREATMENT	N	P	K	Mg	Ca	S	Na	Zn	Cu	B	Al	Fe	Mn
	% dry weight							ppm dry weight					
Biochar + Compost	3.62	0.26	1.22	0.48	2.50	0.21	0.01	90	9	58	108	109	83
Biochar	3.68	0.27	1.16	0.50	2.70	0.22	0.01	86	9	57	114	112	87
Compost	3.62	0.26	1.19	0.45	2.32	0.25	0.02	133	9	70	131	109	79
None	3.67	0.27	1.16	0.47	2.50	0.24	0.02	128	9	72	125	105	75
Biochar	*ns*	*ns*	*ns*	*ns*	*ns*	*0.05*	*0.05*	*0.05*	*ns*	*ns*	*0.05*	*ns*	*ns*
Compost	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Biochar x Compost	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Rep	*ns*	*ns*	*0.05*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

Bloom Leaf Blade Analysis 2023													
TREATMENT	N	P	K	Mg	Ca	S	Na	Zn	Cu	B	Al	Fe	Mn
	% dry weight							ppm dry weight					
Biochar + Compost	3.35	0.23	1.04	0.29	1.70	0.44	0.02	267	10	45	168	140	69
Biochar	3.45	0.24	0.96	0.28	1.62	0.42	0.02	261	9	44	158	135	66
Compost	3.28	0.21	0.92	0.43	1.57	0.40	0.02	257	8	40	146	119	60
None	3.29	0.22	0.95	0.30	1.77	0.43	0.02	266	8	42	153	125	67
Biochar	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Compost	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Biochar x Compost	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Rep	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*	*ns*

Vine Water Status: Midday leaf water potential

2022		
Treatment	**30-Jun**	**21-Jul**
Biochar + compost	9.8	9.4
Biochar	11.2	9.7
Compost	11.1	9.5
Control	10.0	9.3
Biochar	ns	ns
Compost	ns	ns
Bio x Comp	ns	ns
Rep	ns	ns

2023					
Treatment	**Pre-Veraison**		**Veraison**	**Post-Veraison**	
	20-Jul	**2-Aug**	**17-Aug**	**31-Aug**	**7-Sep**
Biochar + Compost	12.4	14.0	14.3	16.0	13.5
Biochar	12.5	13.5	14.7	15.1	14.0
Compost	12.8	14.0	14.5	16.1	14.8
Control	13.0	14.0	15.3	15.6	15.1
Biochar	ns	ns	ns	ns	ns
Compost	ns	ns	ns	ns	ns
Bio x Comp	ns	ns	ns	ns	ns
Rep	ns	ns	ns	ns	ns

Vineyard Yield and Production

Treatment	2022 Vintage			2023 Vintage		
	Clusters per Vine	**Yield (kg/vine)**	**Avg Clust Wt (g)**	**Clusters per Vine**	**Yield (kg/vine)**	**Avg Clust Wt (g)**
Biochar + Compost	39.4	4.98	126	62.7	7.02	112
Biochar	43.8	5.44	125	61.9	6.82	110
Compost	41.0	5.45	132	66.2	7.67	114
Control	40.6	5.25	131	68.6	7.94	116
Biochar	ns	ns	ns	ns	ns	ns
Compost	ns	ns	ns	ns	ns	ns
Bio x Comp	ns	ns	ns	ns	ns	ns
Rep	ns	ns	ns	ns	ns	ns

Grape Composition at Fruit Maturity

Treatment	2022 (Sept 14)			2023 (Oct 20)		
	Brix	pH	TA (g/l)	Brix	pH	TA (g/l)
Biochar + Compost	24.5	3.33	5.90	24.3	3.20	5.38
Biochar	25.6	3.36	5.90	24.2	3.18	5.60
Compost	25.2	3.38	5.93	23.9	3.20	5.59
Control	26.7	3.40	5.57	24.5	3.18	5.52
Biochar	***ns***	***ns***	***ns***	**ns**	**ns**	**ns**
Compost	***0.05***	***ns***	***ns***	**ns**	**ns**	**ns**
Bio x Comp	***ns***	***ns***	***ns***	**0.05**	**ns**	**ns**
Rep	***ns***	***ns***	***ns***	**ns**	**ns**	**ns**

MOVING THE NEEDLE
C Sequestration

	Units	Biochar Application	Compost Application	Compost + Biochar
Application Rates				
	tons / acre	10.21	19.79	30.00
Carbon applied				
	tons / acre	2.83	3.36	6.19
CO_2 equivalent				
Potentially	**metric tons /acre**	9.4	11.2	20.6
Measured	**metric tons /acre**	2.3	-6.0	16.6
$ / metric tons CO_2				
Potentially	**$/Mg CO_2**	$ 362.44	$ 101.02	$ 220.31
Measured	**$/Mg CO_3**	$ 1,481.28	1,131.38	$ 273.39

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