Biochar Use In Viticulture

Report prepared by :

DOVETAIL PARTNERS

USBI

International Biochar Initiative

Biochar has been successfully used in viticulture to boost productivity through improved plant and soil health without negative effects to the grape or wine flavor. There is a large body of research supporting the application of biochar in viticulture specifically, as well as in soils and compost generally.

With biochar matched appropriately to the soils at establishment, growers have seen a 2 to 3 harvest payback on their investment. The increasing need for improved water management is one of the prime benefits seen in vineyards, and that need is expected to intensify as a changing climate affects water availability further. An additional benefit to an investment in biochar is its longevity—measured in decades to millennia—which also opens the potential for economic benefit from the developing carbon credit markets.

Biochar is the product of heating organic feedstocks[1] in a low oxygen environment, a process called pyrolysis. Biochar's primary characteristic is its large surface area, which allows it to address these grape grower's needs:

- Increase water retention
- Increase soil carbon
- Nutrient release leveling
- Soil structure management
- Soil biota improvement
- Soil contamination mitigation
- Pruning and marc disposal (by serving as a feedstock for biochar production)

From the growers' experiences provided in the full report [2], you can see there have been significant successes using biochar in vineyards. The clearest benefit of biochar is its water holding capacity, but the nutrient leveling effects and increased soil carbon (SOM) are also demonstrated in grower's increased productivity. While the soil characteristics were not identified by most growers, it's a critical factor when considering biochar enhancement, whether in the soil or as compost/mulch.

[1]Feedstocks range from woody to grassy, bones, manure, livestock litters, and other inputs to create specialized chars.

[2]Dovetail Report: Biochar Use in Viticulture

THIRD HARVEST REPORT, OASIS VINEYARD FIELD TRIAL WITH BIOCHAR AND COMPOST - https://pacificbiochar.com/vineyard-field-trial-with-biochar-and-compost_-3rd-harvest-report/

Meta-analysis review, Schmidt et al, 2021 - https://onlinelibrary.wiley.com/doi/full/10.1111/gcbb.12889

Biochar Use in Viticulture: Project Team

- Kathleen Draper, Chair, *International Biochar Initiative*
- Harry Groot, *Dovetail Partners*
- Ashley McFarland, *Dovetail Partners*
- Tom Miles, Chair, *US Biochar Initiative*

International Biochar Initiative

USBI

Building the future from the ground up.™

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Project Overview

- The project explored the potential for using biochar in three applications:
  - Viticulture, Livestock and Poultry, and Stormwater Management.
- The process used was to:
  - Interview experienced users
  - Review relevant published scientific research
  - Analyze needs of users and other market data
  - Provide educational outreach
    - Reports
    - Webinars

Report Highlights

- Biochar has been successfully used in viticulture to boost productivity through improved plant and soil health without negative effects to the grape or wine flavor.
- There is a large body of research supporting the application of biochar in viticulture specifically, as well as in soils and compost generally.
- There are many suppliers of biochar in the major grape growing regions of the US.

Today's Speakers

- **Kathleen Draper**–Finger Lakes Biochar (NY), Co-Author of *Burn–Using Fire to Cool the Earth*, IBI Chair, USBI Board member
- **Josiah Hunt**–Pacific Biochar Benefit Corp., USBI Board member
- **Doug Beck**–Monterey Pacific Inc.

Practical Application of Biochar in Vineyards

Doug Beck
Monterey Pacific Inc.
Josiah Hunt
Pacific Biochar Benefit Co.

6
C
CARBON



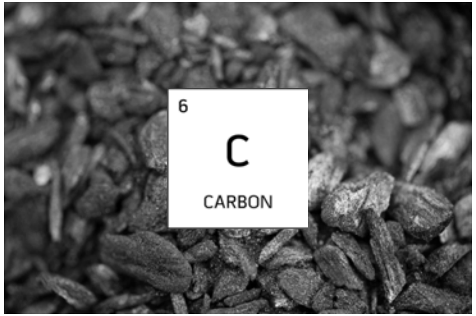

6
C
CARBON


PACIFIC
BIOCHAR


PACIFIC
BIOCHAR


PACIFIC
BIOCHAR

"When the carbon is worth more in the ground than it is in the furnace…"



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Farmland
Improvement,
Potting Media, etc.

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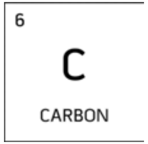

Carbon Dioxide Removal, Voluntary Markets

Farmland Improvement, Potting Media, etc.

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DOI: 10.1111/gcbb.12889

RESEARCH REVIEW

GCB-BIOENERGY WILEY

Biochar in agriculture – A systematic review of 26 global meta-analyses

Hans-Peter Schmidt[1] | Claudia Kammann[2] | Nikolas Hagemann[3,4] | Jens Leifeld[4] | Thomas D. Bucheli[4] | Miguel Angel Sánchez Monedero[5] | Maria Luz Cayuela[5]

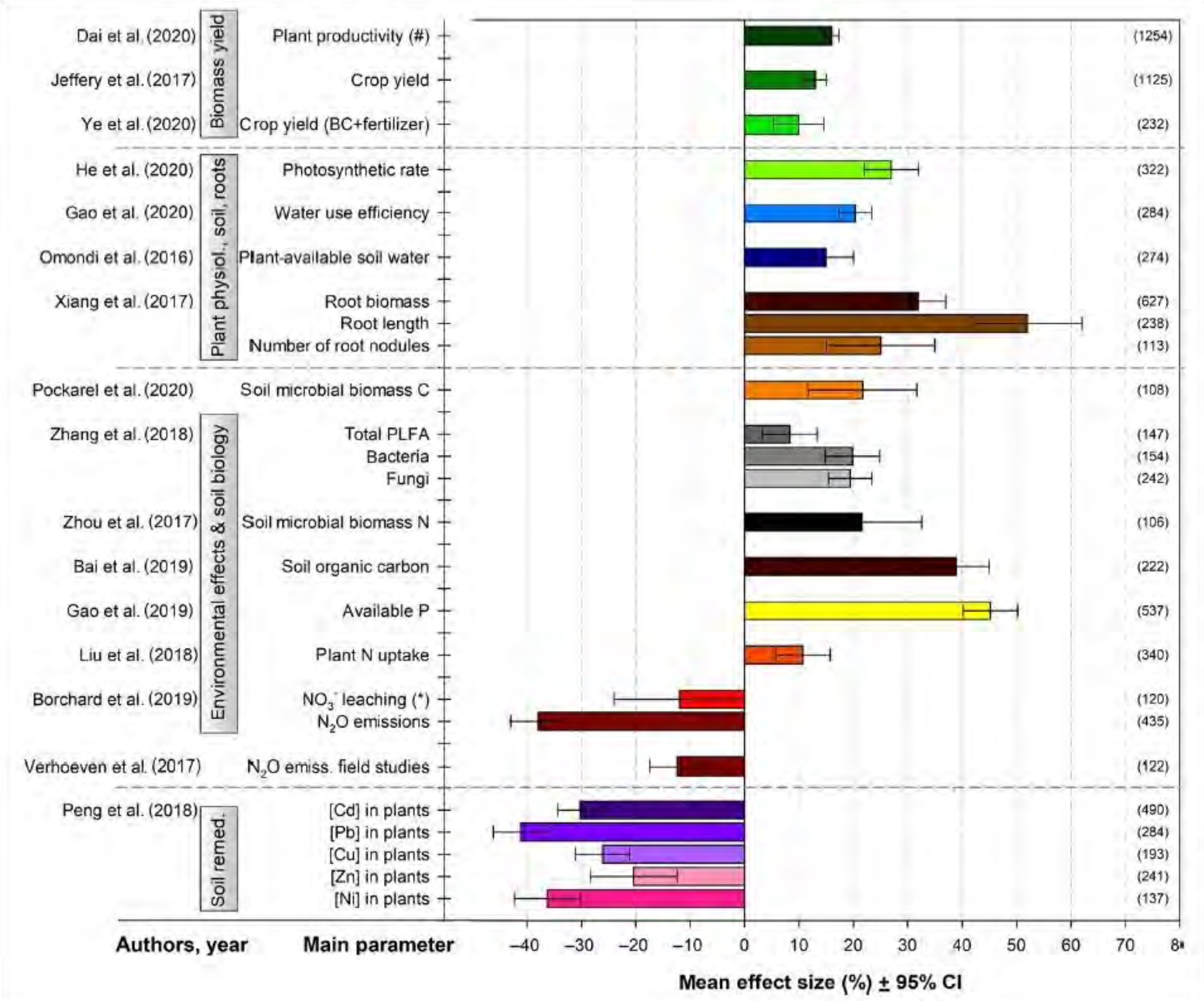


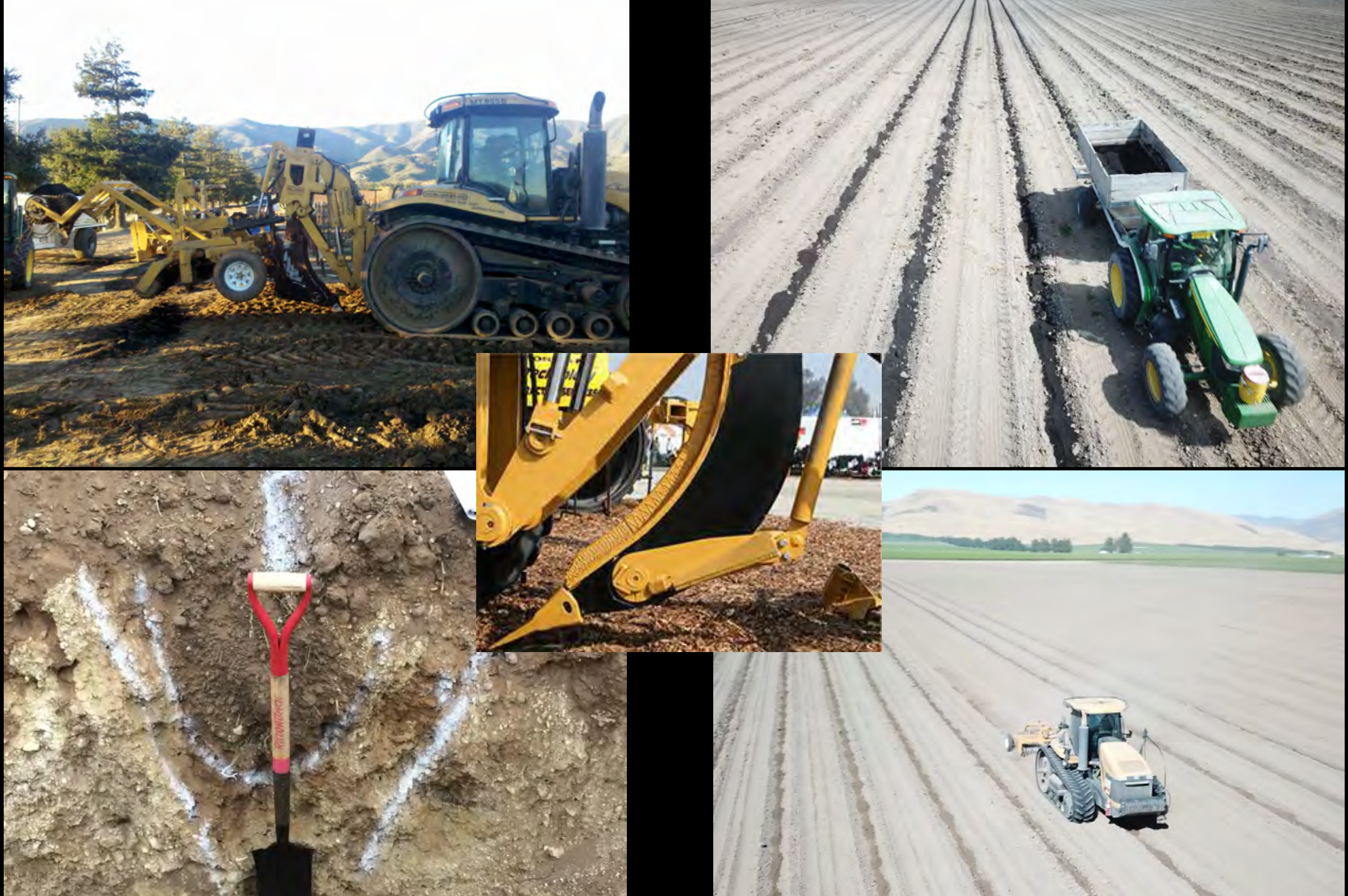
FIGURE 2 Selected parameters with highest agronomic relevance that were investigated in the 26 reviewed meta-analyses. The mean overall effect size (% change) and 95% confidence intervals are given as reported in the original studies. The numbers in parentheses indicate the number of pairwise comparisons used for that specific parameter

Burn to generate electricity?

Pyrolize to biochar,
and bury?

Oasis Vineyard Biochar Trial

California Dept. of Water Resources, University of California - Riverside, Sonoma Ecology Center, Monterey Pacific Inc, & Pacific Biochar



Oasis Vineyard Trial 2017-2020

Treatments:

All treatments applied at depth down planting row (delved) in random pattern (4 replicates) across 8 acre trial area with standard annual fertilizer applications across all blocks

a. Control - 0 tons/acre compost, 0 tons/acre biochar
b. Compost 15 - 15 tons/acre compost
c. Biochar 10 - 10 tons/acre biochar
d. Compost + Biochar - 15 tons/acre compost, 10 tons/acre biochar

Applying biochar and compost to a DWR vineyard field trial.

%OM Calculations for Vineyard Treatments

Cultivated Area_ Soil Volume and Weight

Cu ft / vine	vine / acre	cu ft / acre	cu yd / acre	soil density g/cm	soil density ton/cy	tons soil/acre
25	1089	27225	1008	1.3	1.10	1104.64

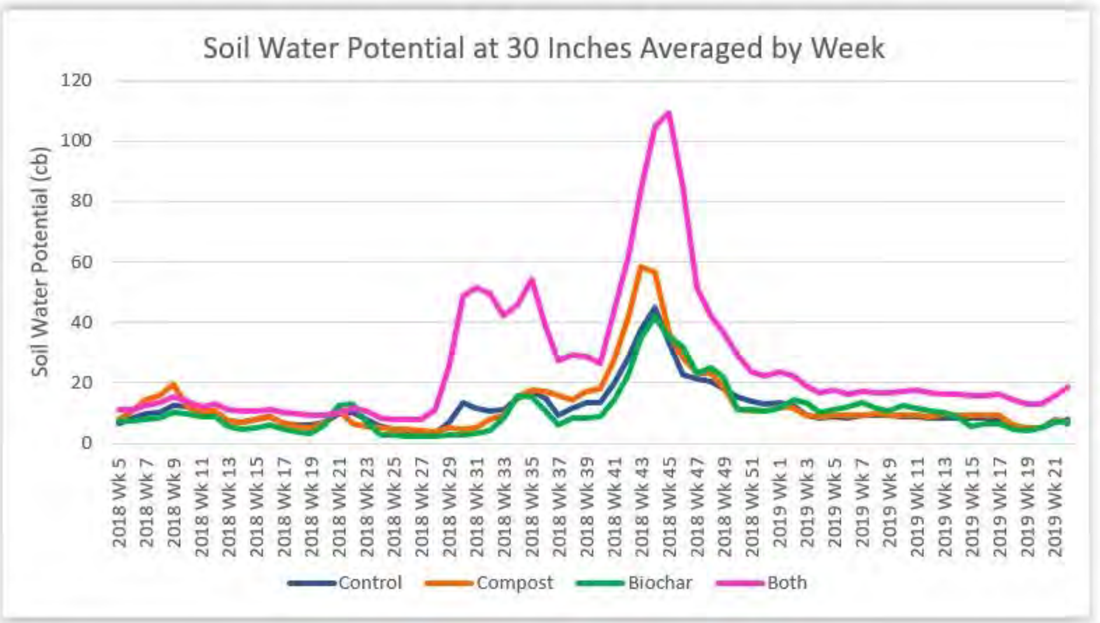
Biochar Application Rate_ Ton/acre Input, %OM Output

	biochar applied (wet ton)	biochar moisture %	biochar applied (dry ton)	biochar OM content	tons OM applied	**% SOM achieved**
Biochar	10.00	38%	6.18	74.50%	4.60	**0.42%**

Compost Application Rate_ Ton/acre Input, %OM Output

	compost applied (wet ton)	compost moisture %	compost applied (dry ton)	compost OM content	tons OM applied	**% SOM achieved**
Compost	15.00	49%	7.70	42.50%	3.27	**0.30%**


UCRIVERSIDE

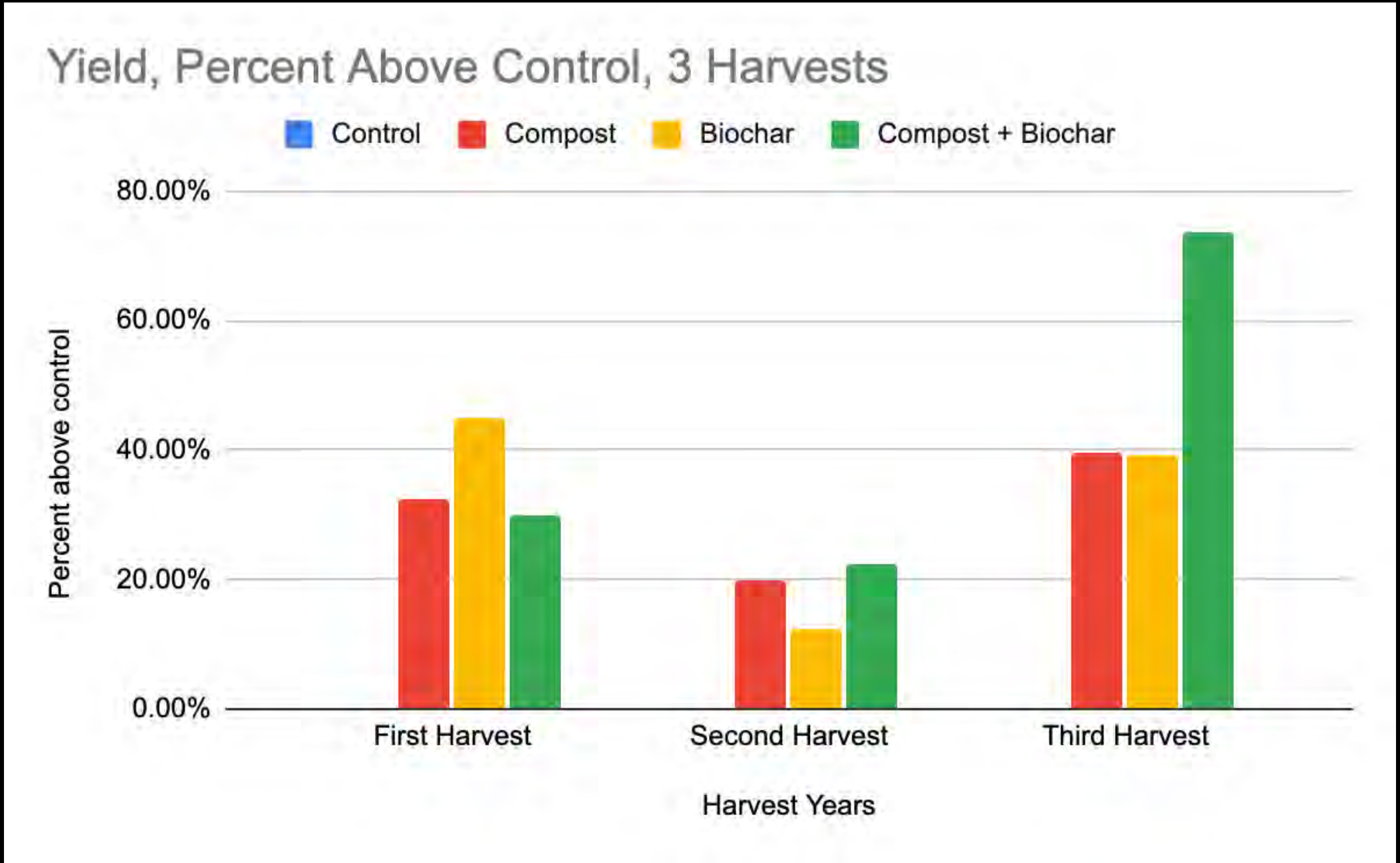

Soil Water Potential at 30 Inches Averaged by Week
Soil Water Potential (cb)
120
100
80
60
40
20
0
2018 Wk 5
2018 Wk 7
2018 Wk 9
2018 Wk 11
2018 Wk 13
2018 Wk 15
2018 Wk 17
2018 Wk 19
2018 Wk 21
2018 Wk 23
2018 Wk 25
2018 Wk 27
2018 Wk 29
2018 Wk 31
2018 Wk 33
2018 Wk 35
2018 Wk 37
2018 Wk 39
2018 Wk 41
2018 Wk 43
2018 Wk 45
2018 Wk 47
2018 Wk 49
2018 Wk 51
2019 Wk 1
2019 Wk 3
2019 Wk 5
2019 Wk 7
2019 Wk 9
2019 Wk 11
2019 Wk 13
2019 Wk 15
2019 Wk 17
2019 Wk 19
2019 Wk 21
Control
Compost
Biochar
Both

Harvest 2019 3rd Leaf		Yield	Cluster #	Cluster lb
R1		2.78	26.40	0.31
R2	Control	3.73	28.70	0.27
R3		2.82	23.10	0.25
R4		2.42	26.30	0.31
Control Average		**2.94**	**26.13**	**0.29**
R1		4.04	30.60	0.27
R2	Compost	3.30	27.10	0.25
R3		4.20	33.20	0.26
R4		4.02	27.60	0.30
Compost Average		**3.89**	**29.63**	**0.27**
R1		3.94	28.50	0.29
R2	Biochar	4.90	39.60	0.26
R3		3.63	27.30	0.28
R4		4.55	33.30	0.28
Biochar Average		**4.26**	**32.18**	**0.28**
R1		3.78	26.80	0.29
R2	Compost + Biochar	3.58	24.40	0.30
R3		3.83	36.90	0.21
R4		4.08	31.50	0.27
Compost-Bio Average		**3.82**	**29.90**	**0.27**

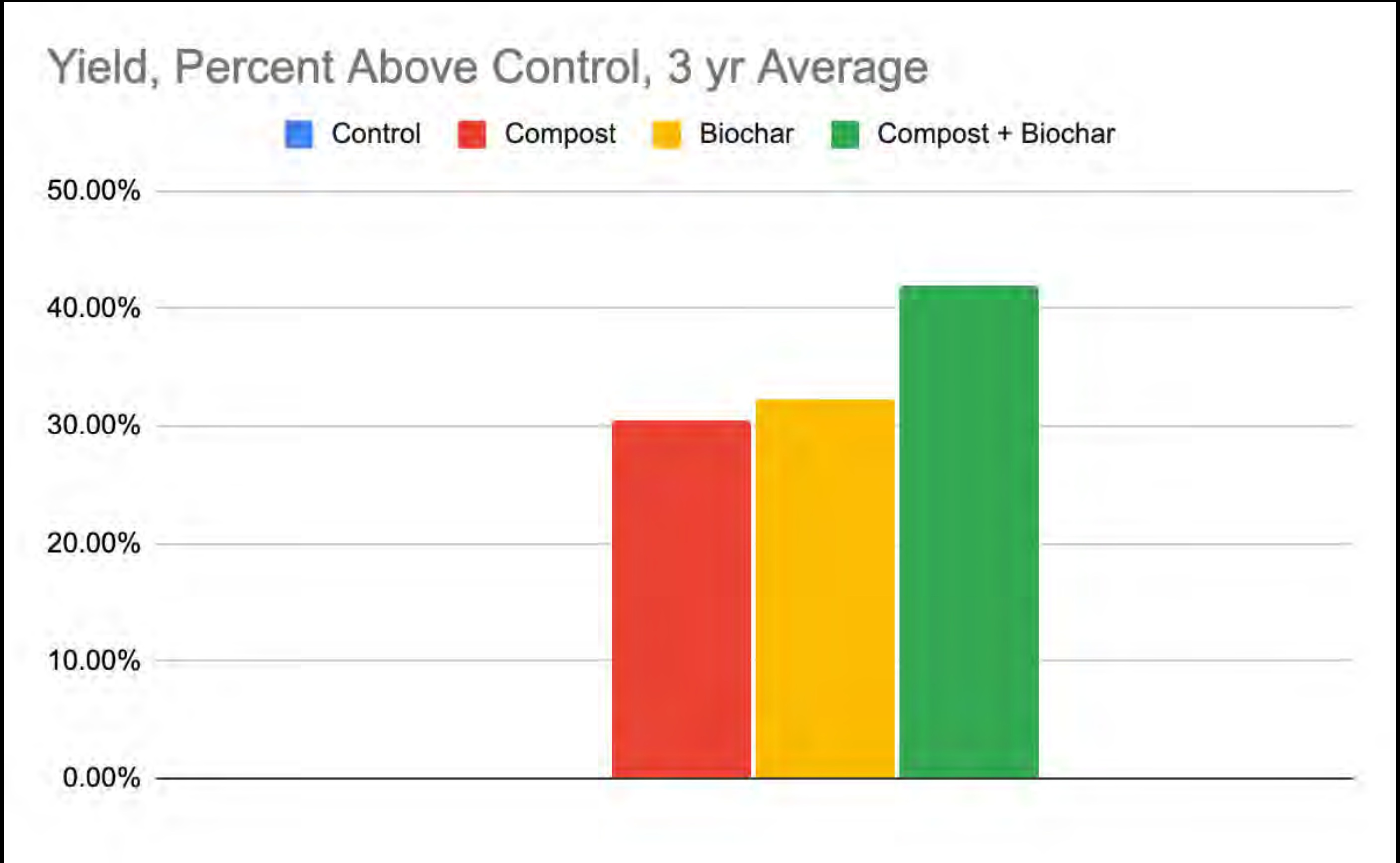
Harvest 2020 4th Leaf		Yield	Cluster #	Cluster lb
R1		9.22	54.60	0.31
R2	Control	10.12	53.95	0.34
R3		8.66	46.60	0.34
R4		8.00	41.85	0.35
Control Average		**9.00**	**49.25**	**0.34**
R1		10.37	55.25	0.34
R2	Compost	10.72	54.30	0.36
R3		11.39	62.60	0.33
R4		10.68	54.45	0.36
Compost Average		**10.79**	**56.65**	**0.35**
R1		10.71	57.00	0.34
R2	Biochar	10.79	57.40	0.35
R3		10.72	58.50	0.34
R4		8.27	45.55	0.33
Biochar Average		**10.12**	**54.61**	**0.34**
R1		11.21	58.80	0.35
R2	Compost + Biochar	10.23	55.15	0.34
R3		13.09	65.10	0.37
R4		9.57	49.85	0.35
Compost-Bio Average		**11.02**	**57.23**	**0.35**

Harvest 2020 4th Leaf		Yield	Cluster #	Cluster lb
R1		9.22	54.60	0.31
R2	Control	10.12	53.95	0.34
R3		8.66	46.60	0.34
R4		8.00	41.85	0.35
Control Average		**9.00**	**49.25**	**0.34**
R1		10.37	55.25	0.34
R2	Compost	10.72	54.30	0.36
R3		11.39	62.60	0.33
R4		10.68	54.45	0.36
Compost Average		**10.79**	**56.65**	**0.35**
R1		10.71	57.00	0.34
R2	Biochar	10.79	57.40	0.35
R3		10.72	58.50	0.34
R4		8.27	45.55	0.33
Biochar Average		**10.12**	**54.61**	**0.34**
R1		11.21	58.80	0.35
R2	Compost + Biochar	10.23	55.15	0.34
R3		13.09	65.10	0.37
R4		9.57	49.85	0.35
Compost-Bio Average		**11.02**	**57.23**	**0.35**

Harvest 2021 5th Leaf		Yield	Cluster #	Cluster lb
R1		2.897	25.40	0.21
R2	Control	3.376	30.25	0.20
R3		4.438	56.15	0.15
R4		4.62	48.60	0.17
Control Average		**3.833**	**40.10**	**0.18**
R1		4.397	33.40	0.24
R2	Compost	3.762	37.20	0.19
R3		6.044	49.65	0.22
R4		7.193	65.85	0.20
Compost Average		**5.349**	**46.53**	**0.21**
R1		4.108	32.30	0.23
R2	Biochar	5.418	45.40	0.22
R3		6.161	52.95	0.21
R4		5.685	50.05	0.21
Biochar Average		**5.343**	**45.18**	**0.22**
R1		4.775	36.50	0.24
R2	Compost + Biochar	6.382	41.00	0.29
R3		7.914	63.80	0.23
R4		7.533	68.30	0.20
Compost-Bio Average		**6.651**	**52.40**	**0.24**



Yield, Percent Above Control, 3 Harvests
Control
Compost
Biochar
Compost + Biochar
80.00%
60.00%
40.00%
20.00%
0.00%
Percent above control
First Harvest
Second Harvest
Third Harvest
Harvest Years



Yield, Percent Above Control, 3 yr Average
Control
Compost
Biochar
Compost + Biochar
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%

Compost Analysis

Nutrients	Dry wt.	As Rcvd.	units
Total Nitrogen:	1.5	0.79	%
Ammonia (NH_4-N):	18	9.1	mg/kg
Nitrate (NO_3-N):	450	230	mg/kg
Org. Nitrogen (Org.-N):	1.5	0.77	%
Phosphorus (as P_2O_5):	3.7	1.9	%
Phosphorus (P):	16000	8300	mg/kg
Potassium (as K_2O):	7.9	4.1	%
Potassium (K):	66000	34000	mg/kg
Calcium (Ca):	27	14	%
Magnesium (Mg):	2.7	1.4	%
Sulfate (SO_4-S):	4000	2000	mg/kg
Boron (Total B):	110	58	mg/kg
Moisture:	0	48.7	%
Sodium (Na):	1.6	0.83	%
Chloride (Cl):	0.83	0.43	%
pH Value:	NA	7.59	unit
Bulk Density :	21	41	lb/cu ft
Carbonates ($CaCO_3$):	130	66	lb/ton
Conductivity (EC5):	13	NA	mmhos/cm
Organic Matter:	42.5	21.8	%
Organic Carbon:	22.0	11.0	%
Ash:	57.5	29.5	%
C/N Ratio	14	14	ratio
AgIndex	5	5	ratio

Stability Indicator: CO2 Evolution	Respirometery	Biologically Available C
mg CO_2-C/g OM/day	0.73	1.0
mg CO_2-C/g TS/day	0.31	0.44
Stability Rating	*very stable*	*very stable*

Maturity Indicator: Cucumber Bioassay	
Compost:Vermiculite(v:v)	1:2
Emergence (%)	93
Seedling Vigor (%)	109
Description of Plants	*healthy*

Pathogens	Results	Units	Rating
Fecal Coliform	8.5	MPN/g	*pass*
Salmonella	< 3	MPN/4g	*pass*

Date Tested: 20 Apr. 16

Inerts	% by weight
Plastic	< 0.5
Glass	< 0.5
Metal	< 0.5
Sharps	ND

P per ton Compost at 8,300 ppm is about 17 lb/ton
=255 lb P per 15 tons compost or **0.26 lb/vine**

K per ton Compost at 34,000 ppm is about 68 lb/ton or
=1,020 lb K per 15 tons compost or **1 lb/vine**

Biochar Analysis

International BioChar Initiative (IBI) Laboratory Tests for Certification Program

Dry Basis Unless Stated:		Range	Units	Method
Moisture (time of analysis)	38.2		% wet wt.	ASTM D1762-84 (105c)
Bulk Density	10.6		lb/cu ft	
Organic Carbon	68.0		% of total dry mass	Dry Combust-ASTM D 4373
Hydrogen/Carbon (H:C)	0.30	0.7 Max	Molar Ratio	H dry combustion/C(above)
Total Ash	25.5		% of total dry mass	ASTM D-1762-84
Total Nitrogen	0.69		% of total dry mass	Dry Combustion

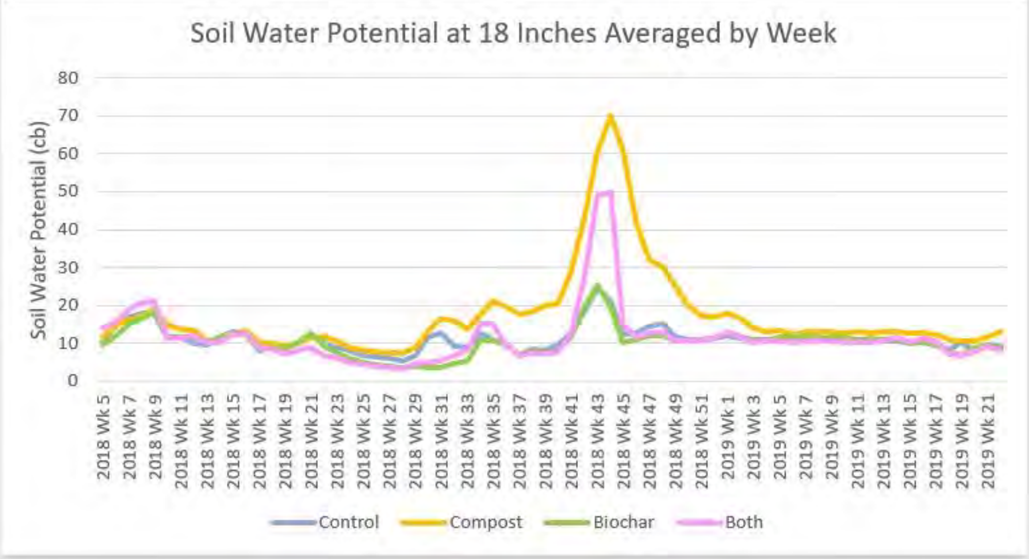
Basic Soil Enhancement Properties			
Total (K)	19554	mg/kg	E
Total (P)	2738	mg/kg	E
Ammonia (NH4-N)	13.4	mg/kg	A
Nitrate (NO3-N)	10.2	mg/kg	A
Organic (Org-N)	6856	mg/kg	Calc.

P per ton Biochar at 2,738 ppm dry weight is about 3 lbs per ton as delivered

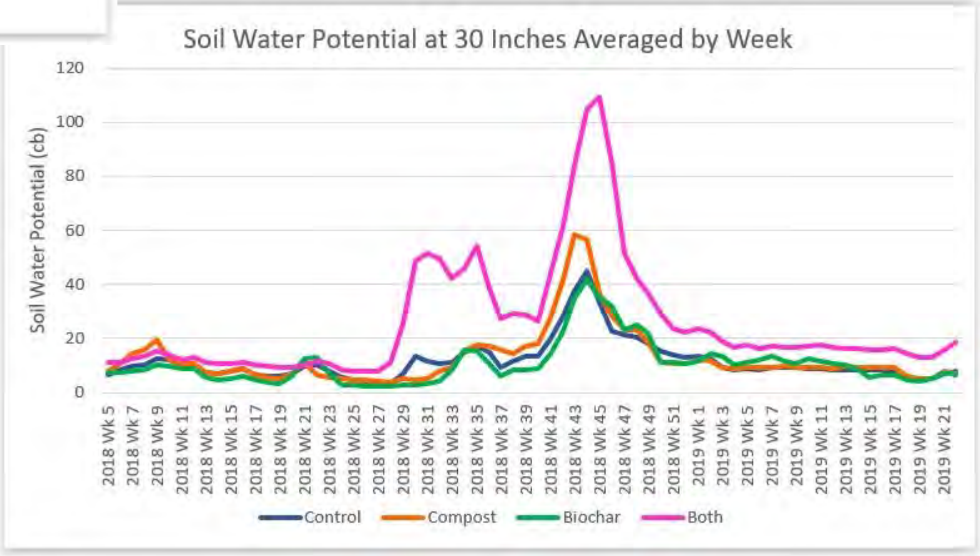
=33 lb P per 10 tons biochar or **0.03 lb/vine**

K per ton Biochar at 19,554 ppm dry weight is about 23 lb/ton as delivered

=230 lb K per 10 tons biochar or **0.24 lb/vine**



Soil Water Potential at 18 Inches Averaged by Week
Soil Water Potential (cb)
0
10
20
30
40
50
60
70
80
2018 Wk 5
2018 Wk 7
2018 Wk 9
2018 Wk 11
2018 Wk 13
2018 Wk 15
2018 Wk 17
2018 Wk 19
2018 Wk 21
2018 Wk 23
2018 Wk 25
2018 Wk 27
2018 Wk 29
2018 Wk 31
2018 Wk 33
2018 Wk 35
2018 Wk 37
2018 Wk 39
2018 Wk 41
2018 Wk 43
2018 Wk 45
2018 Wk 47
2018 Wk 49
2018 Wk 51
2019 Wk 1
2019 Wk 3
2019 Wk 5
2019 Wk 7
2019 Wk 9
2019 Wk 11
2019 Wk 13
2019 Wk 15
2019 Wk 17
2019 Wk 19
2019 Wk 21
Control
Compost
Biochar
Both



Soil Water Potential at 30 Inches Averaged by Week
Soil Water Potential (cb)
0
20
40
60
80
100
120
2018 Wk 5
2018 Wk 7
2018 Wk 9
2018 Wk 11
2018 Wk 13
2018 Wk 15
2018 Wk 17
2018 Wk 19
2018 Wk 21
2018 Wk 23
2018 Wk 25
2018 Wk 27
2018 Wk 29
2018 Wk 31
2018 Wk 33
2018 Wk 35
2018 Wk 37
2018 Wk 39
2018 Wk 41
2018 Wk 43
2018 Wk 45
2018 Wk 47
2018 Wk 49
2018 Wk 51
2019 Wk 1
2019 Wk 3
2019 Wk 5
2019 Wk 7
2019 Wk 9
2019 Wk 11
2019 Wk 13
2019 Wk 15
2019 Wk 17
2019 Wk 19
2019 Wk 21
Control
Compost
Biochar
Both

4th Leaf Grape Quality

Titratable Acidity

AVERAGES	mg/L	% difference	ST DEV
Control	6.425	0.00%	0.26
Compost	6.375	-0.78%	0.29
Biochar	6.375	-0.78%	0.33
Com+Biochar	6.25	-2.72%	0.24

pH

AVERAGES	pH	% difference	ST DEV
Control	3.3925	0.00%	0.08
Compost	3.4125	0.59%	0.09
Biochar	3.4275	1.03%	0.12
Com+Biochar	3.4575	1.92%	0.09

Brix

AVERAGES	brix	% difference	ST DEV
Control	23.875	0.00%	1.01
Compost	23.35	-2.20%	0.47
Biochar	24.25	1.57%	0.99
Com+Biochar	23.75	-0.52%	0.87

Harvest 2020 4th Leaf		Yield	Cluster #	Cluster lb
R1		9.22	54.60	0.31
R2	Control	10.12	53.95	0.34
R3		8.66	46.60	0.34
R4		8.00	41.85	0.35
Control Average		**9.00**	**49.25**	**0.34**
R1		10.37	55.25	0.34
R2	Compost	10.72	54.30	0.36
R3		11.39	62.60	0.33
R4		10.68	54.45	0.36
Compost Average		**10.79**	**56.65**	**0.35**
R1		10.71	57.00	0.34
R2	Biochar	10.79	57.40	0.35
R3		10.72	58.50	0.34
R4		8.27	45.55	0.33
Biochar Average		**10.12**	**54.61**	**0.34**
R1		11.21	58.80	0.35
R2	Compost + Biochar	10.23	55.15	0.34
R3		13.09	65.10	0.37
R4		9.57	49.85	0.35
Compost-Bio Average		**11.02**	**57.23**	**0.35**

4^{th} Leaf Berry Size

Berry Weight

AVERAGES	g/berry	% difference	ST DEV
Control	1.3675	0.00%	0.02
Compost	1.33	-2.74%	0.05
Biochar	1.3925	1.83%	0.05
Com+Biochar	1.3575	-0.73%	0.02

Berry Volume

AVERAGES	ml/berry	% difference	ST DEV
Control	1.1475	0.00%	0.04
Compost	1.185	3.27%	0.07
Biochar	1.24*	8.06%	0.08
Com+Biochar	1.15	0.22%	0.03

Sugar per Berry

AVERAGES	mg/berry	% difference	ST DEV
Control	271.5	0.00%	12.48
Compost	273	0.55%	16.15
Biochar	298.5*	9.94%	12.79
Com+Biochar	270.5	-0.37%	16.82

Harvest 2020 4th Leaf		Yield	Cluster #	Cluster lb
R1		9.22	54.60	0.31
R2	Control	10.12	53.95	0.34
R3		8.66	46.60	0.34
R4		8.00	41.85	0.35
Control Average		**9.00**	**49.25**	**0.34**
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R4		9.57	49.85	0.35
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4th Leaf Grape Color?

Polymeric Anthocyanins

AVERAGES	mg/L	% difference	ST DEV
Control	6.25	0.00%	0.9574
Compost	6.00	-4.00%	0.0000
Biochar	6.50	4.00%	0.5774
Com+Biochar	5.75	-8.00%	0.5000

Tannin

AVERAGES	mg/L	% difference	ST DEV
Control	207.50	0.00%	18.9473
Compost	200.25	-3.49%	18.9978
Biochar	211.75	2.05%	22.3961
Com+Biochar	201.00	-3.13%	20.4124

Total Anthocyanins

AVERAGES	mg/L	% difference	ST DEV
Control	627.50	0.00%	63.1057
Compost	628.50	0.16%	15.3514
Biochar	659.75	5.14%	49.5202
Com+Biochar	642.50	2.39%	60.7317

Harvest 2020 4th Leaf		Yield	Cluster #	Cluster lb
R1		9.22	54.60	0.31
R2	Control	10.12	53.95	0.34
R3		8.66	46.60	0.34
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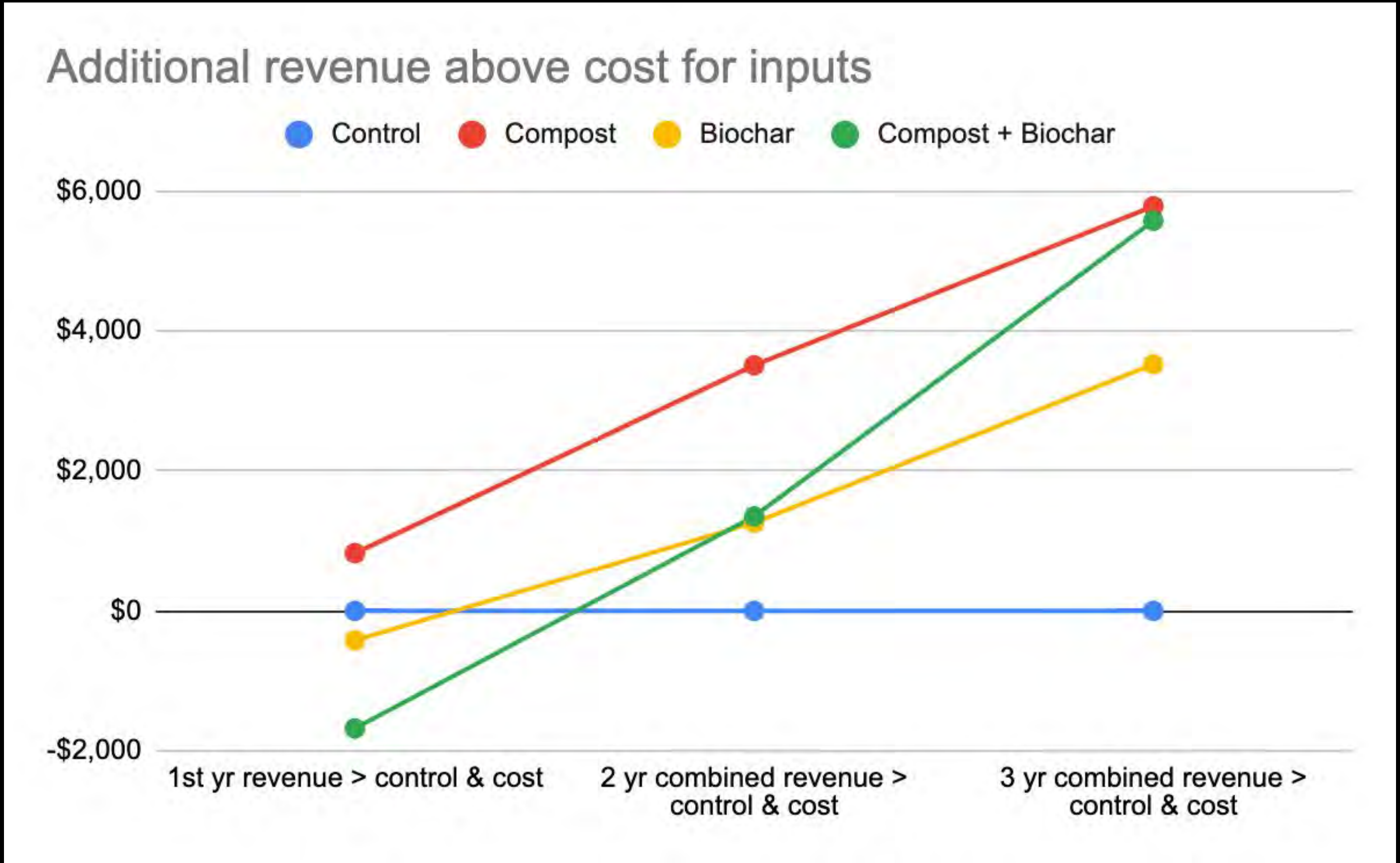
R1		10.37	55.25	0.34
R2	Compost	10.72	54.30	0.36
R3		11.39	62.60	0.33
R4		10.68	54.45	0.36
Compost Average		**10.79**	**56.65**	**0.35**
R1		10.71	57.00	0.34
R2	Biochar	10.79	57.40	0.35
R3		10.72	58.50	0.34
R4		8.27	45.55	0.33
Biochar Average		**10.12**	**54.61**	**0.34**
R1		11.21	58.80	0.35
R2	Compost + Biochar	10.23	55.15	0.34
R3		13.09	65.10	0.37
R4		9.57	49.85	0.35
Compost-Bio Average		**11.02**	**57.23**	**0.35**

Economic Return Assessment on Biochar-Only Application

- Yield Increase 3rd Leaf
  - 2019 +biochar=1.3 ton/acre increase
    Grape price $1500/ton
  - Additional revenue/acre = **$1,950**
- Yield Increase 4th Leaf
  - 2020 +biochar = 1.1 ton/acre increase
  - Grape price $1500/ton
  - Additional revenue/acre = **$1,650**
  - No further amendments cost
- Yield Increase 5th Leaf
  - 2021 +biochar = 1.5 ton/acre increase
  - Grape price $1500/ton
  - Additional Revenue = **$2,250**

- Biochar cost
  - 10 ton/acre
  - Biochar cost $240 per ton
  - Cost/acre = **$2,400**

- Return on Investment
  - Additional revenue $5,850/ac first 3 producing years, **$3450 above cost**
  - Assume additional per year of 0.5 t/ac over no amendments, $5,250 extra/ac over the next 7 years
  - Potentially added $**8,700** income/ac over 10 yrs harvesting



Additional revenue above cost for inputs
Control
Compost
Biochar
Compost + Biochar
$6,000
$4,000
$2,000
$0
-$2,000
1st yr revenue > control & cost
2 yr combined revenue > control & cost
3 yr combined revenue > control & cost

Harvest 2020 4th Leaf		Yield	Cluster #	Cluster lb
R1		9.22	54.60	0.31
R2	Control	10.12	53.95	0.34
R3		8.66	46.60	0.34
R4		8.00	41.85	0.35
Control Average		**9.00**	**49.25**	**0.34**
R1		10.37	55.25	0.34
R2	Compost	10.72	54.30	0.36
R3		11.39	62.60	0.33
R4		10.68	54.45	0.36
Compost Average		**10.79**	**56.65**	**0.35**
R1		10.71	57.00	0.34
R2	Biochar	10.79	57.40	0.35
R3		10.72	58.50	0.34
R4		8.27	45.55	0.33
Biochar Average		**10.12**	**54.61**	**0.34**
R1		11.21	58.80	0.35
R2	Compost + Biochar	10.23	55.15	0.34
R3		13.09	65.10	0.37
R4		9.57	49.85	0.35
Compost-Bio Average		**11.02**	**57.23**	**0.35**

Biochar and Composting

CO-COMPOSTING, BLENDING, & AGING

- Compost is improved
  - Odor control (i.e. ammonia)
  - GHG emission reduction (i.e. CH_4, N_2O, etc.)
  - Reduced nutrient loss, especially N
  - Increased microbial activity & diversity
  - Maturity and stability superior
- Biochar is improved
  - Complexed surface becomes more functional
  - Microbial colonization
  - Nutrient loading
  - Better plant growth response

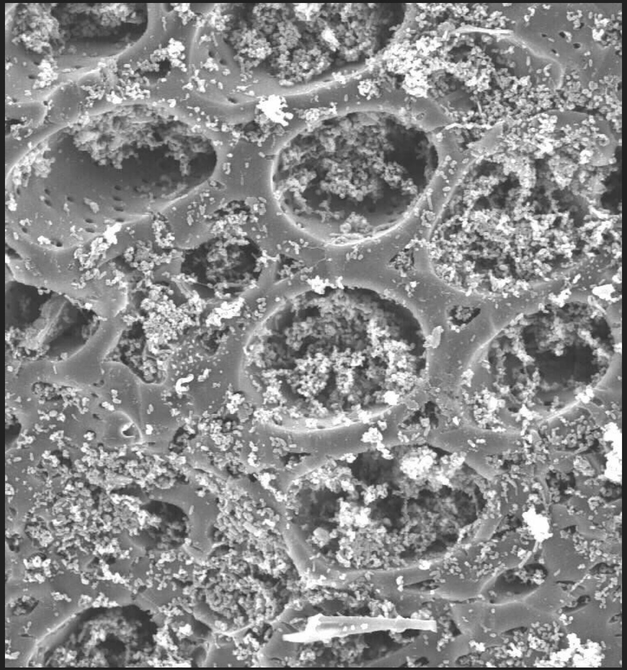
Biochar and Soil Biology

MICROBIAL HABITAT & ROOTS

- Air, water and nutrients are retained in pores and on surfaces
- Organic coating forms on surfaces over time (i.e. biochar “aging”)
- Efficient electron transfer reactions
- Studies consistently demonstrate enhanced biological activity and diversity in soils using biochar

Scanning Electron Microscope Photos of Biochar

Mycorrhizal spore extending hyphae into biochar particle. Photo courtesy of Ogawa [8]



Surface complexing during composting. Photo courtesy of Yoshizawa [9]

Biochar ??

Compost

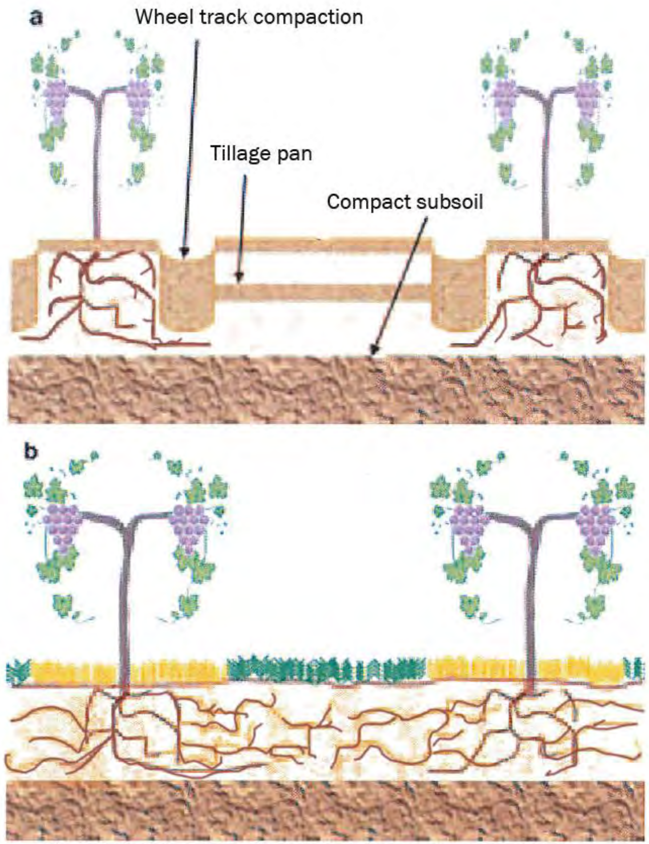
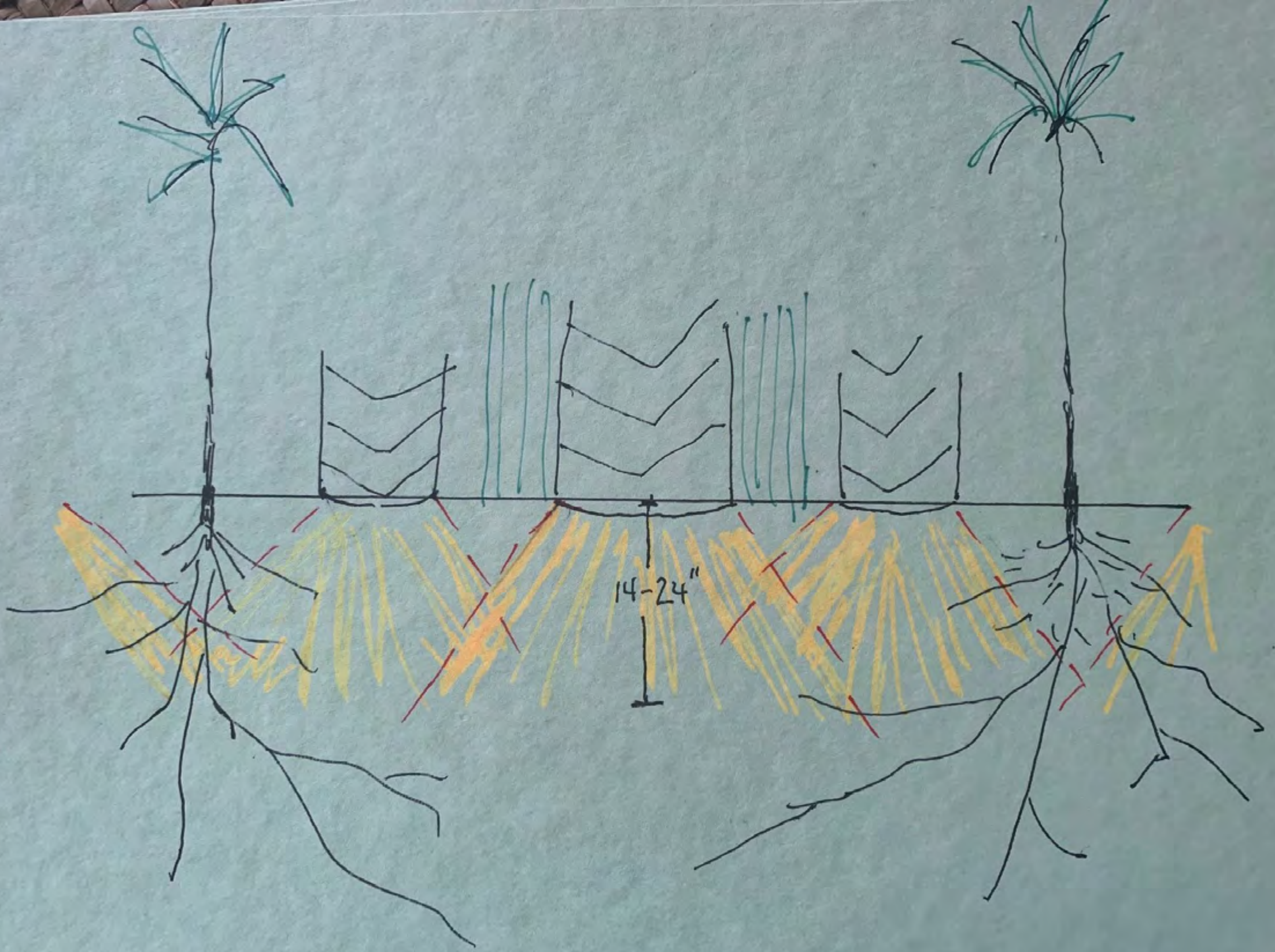
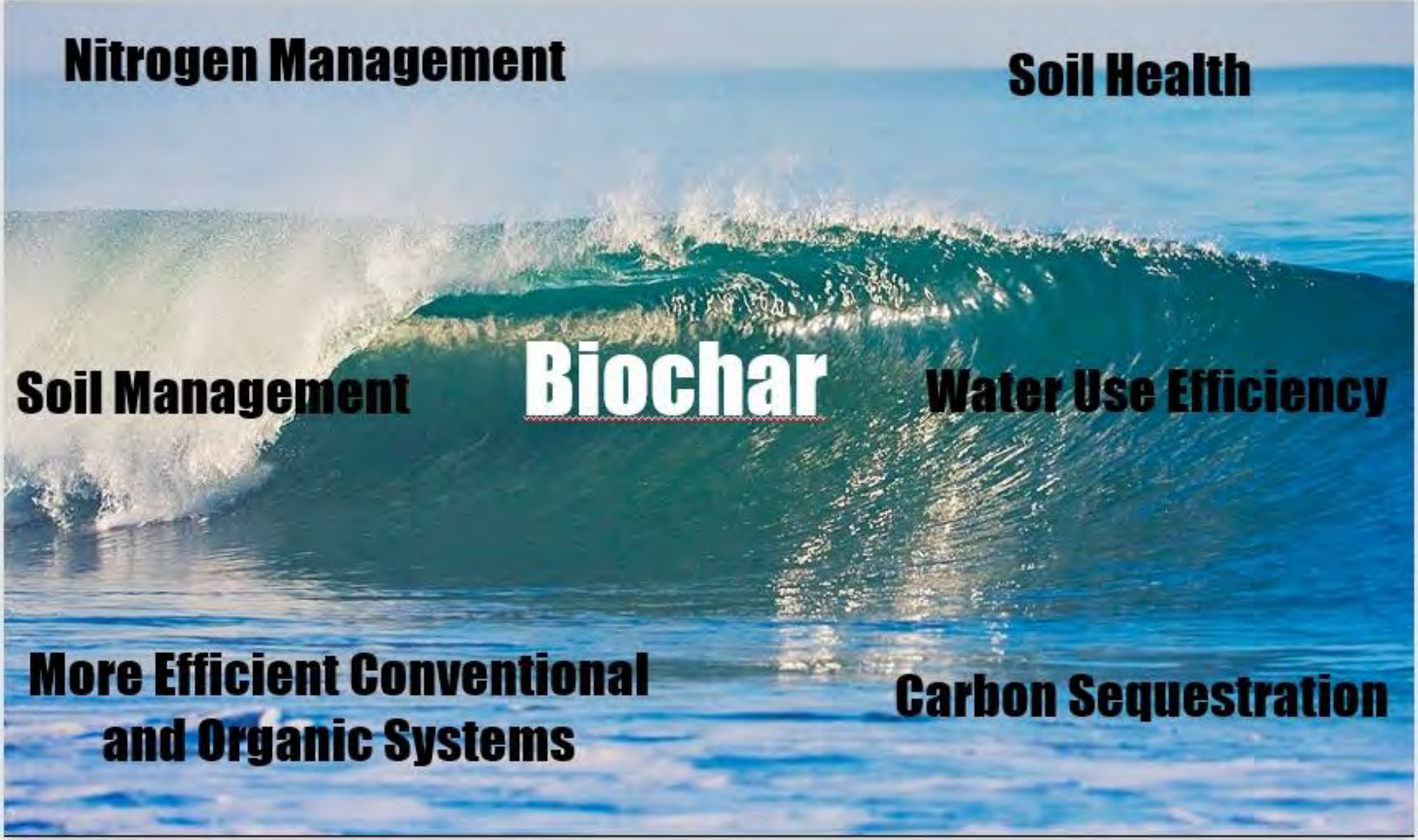


Fig. 10. Schematic cross sectional views of two vine rows showing (a) the most common elements of soil compaction in vineyards and illustrating restricted lateral vine root growth associated with wheel traffic compaction (b) amelioration of wheel, midrow and under-vine crusts and tillage pan compaction showing possible expansion of the vine root system. The under-vine cover crop is represented as being controlled by herbicide application during the growing season.

From A. Cass, 2007 Australian Grape Grower and Winemaker, Annual Technical Issue


14-24"


Wheel track
compaction
Soil Surface
2 Feet
Lateral disturbance
into root zone
Root zone


Nitrogen Management
Soil Health
Soil Management
Biochar
Water Use Efficiency
More Efficient Conventional and Organic Systems
Carbon Sequestration

Resources

- Webinar recording link will be posted at Dovetail, USBI, and IBI
- *Biochar Use in Viticulture* full report: www.dovetailinc.org/portfoliodetail.php?id=61688a6830537 For (www.dovetailinc.org) Click *Reports* tab for the full library
- USBI–(biochar-us.org) broad array of US resources including biochar suppliers www.usbi.org
- International Biochar Initiative–(biochar-international.org) links to biochar related research, analytical resources, educational material, and links to international biochar networks.