Influence of Biochar Additions on Net Greenhouse Gas Production



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Biochar Research

- Benefits of biochar additions to oxisol soils are known

- What happens for other soils with the addition of biochars?

Biochar Research

- Part of new ARS multi-location
Biochar and Pyrolysis Initiative

•6 ARS locations :

Ames, IA; Kimberly, ID; St. Paul, MN;

Big Spring, TX; Florence, SC; Prosser, WA.

- Fast pyrolysis char used in replicated field plots

•Continuous corn (same crop for comparison)

•In addition to following crop yield and soil carbon:

✓ Soil gas concentrations and trace gas fluxes

✓ Seedling Emergence/Initial seedling growth rates

Rosemount Biochar Field Trials

- Small scale triplicate plots (16’ x 16’)

  Largely due to the limited availability of biochar.

(Application rate : 20,000 lbs/acre)

  - Fast pyrolysis biochar (sawdust, CQuest^{TM} Dynamotive[1])
    - With and without manure addition (5,000 lb/acre)
  - Slow pyrolysis biochar (woodchip, Best Energies[1])
  - Slow pyrolysis biochar (macadamia nut, Biochar Brokers[1])
  - Slow pyrolysis updraft gasifier (wood pellets, Chip Energy[1]) [Fall 2009]

- Larger strip plots (16’ x 93’)
  - Hardwood charcoal (ground lump charcoal, Kingsford[1])
  - Slow pyrolysis biochar (macadamia nut, Biochar Brokers[1])
    - 3 rates: 5,000, 10,000 and 20,000 lb/acre

1-Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

Laboratory Studies

- Overview:
  - 24 different biochars evaluated
  - 11 different biomass parent materials
  - Represents a cross-sectional sampling of available “biochars”
    - C content 1 to 84%
    - N content 0.1 to 2.7%
    - Production Temperatures 350 to 850 C

BC #	Parent Material	Source	Pyrolysis Temp (°C)	C	N	O	Ash	Surface Area ($m^2\ g^{-1}$)
1	Corn stover	Best Energies	815	45	0.5	1	55	4.4
2	Pine wood chip	EPRIDA	465	75	0.3	9	6	0.1
3	Peanut hulls	EPRIDA	481	59	2.7	12	15	1.0
4	Corn stover	R. Brown – Iowa State	500	25	0.6	5	69	4.2
5	Corn stover	EPRIDA	410	42	1.0	11	54	2.2
6	*N/A*	Char C Group (Biosource™)	465	43	2.2	*N/A*	*N/A*	63.5
7	Turkey manure Woodchip	SWROC-Univ. of MN	850	1	0.1	3	89	4.8
8	Hardwood	D. Laird (USDA-ARS)	*N/A*	69	0.7	9	14	19.2
9	Pine woodchip	EPRIDA	465	71	0.2	11	9	0.2
10	Peanut hulls	EPRIDA	481	60	0.9	10	15	286
11	Corn stover	EPRIDA	505	66	1.2	4	54	17.3
12	Corn stover	EPRIDA	515	51	1.0	0	74	9.9
13	Coconut shells (Activated)	Willinger Bros.	450	83	0.4	0	12	960
14	Woodchip (pellet)	Chip Energy	*650*	69	0.2	20	6	63
15	Hardwood lump charcoal	Kingsford	538	53	0.4	10	27	7.2
16	Macadamia shells	Biochar Brokers (EternaGreen™)	*N/A*	84	0.6	2	2	0.4

BC #	Parent Material	Source	Pyrolysis Temp (°C)	C	N	O	Ash	Surface Area ($m^2\ g^{-1}$)
17	Distillers grain (ethanol plant residues)	Illinois Sustainable Technology Center (ISTC)	350	N/A	N/A	N/A	N/A	N/A
18	Distillers grain (ethanol plant residues)	ISTC	400	N/A	N/A	N/A	N/A	N/A
19	Corn cob	ISTC	350	N/A	N/A	N/A	N/A	N/A
20	Corn cob	ISTC	400	N/A	N/A	N/A	N/A	N/A
21	Wood waste (mixed)	ISTC	400	N/A	N/A	N/A	N/A	23
22	Wood waste (mixed)	ISTC	500	N/A	N/A	N/A	N/A	27
23	Algae	Univ. of MN	Hydrothermal carbonization	N/A	N/A	N/A	N/A	**0.11**
24	Sawdust	Dynamotive (CQuest™)	550	61	0.2	11	20	46

Weathering impact

BC #	Parent Material	Pyrolysis Temp (^oC)	C	N	O	Ash	Surface Area ($m^2\ g^{-1}$)
3	Peanut hulls (fresh)	481	59	2.7	12	15	1.0
10	Peanut hulls (weathered)	481	66	0.9	10	15	286

Weathered char (1 yr on outdoor storage pile):

- Minor changes in composition data
  - Loss of N → would indicate N is available
- Major change in surface area (286 times)

Laboratory Incubations

Soil incubations used to assess the impacts of these 24 different biochars with soils from 3 different ecosystems:

- Minnesota agricultural soil
  - Waukegan silt loam

- Wisconsin forest nursery soil
  - Vilas loamy sand

- California landfill cover soil
  - Marina loamy sand

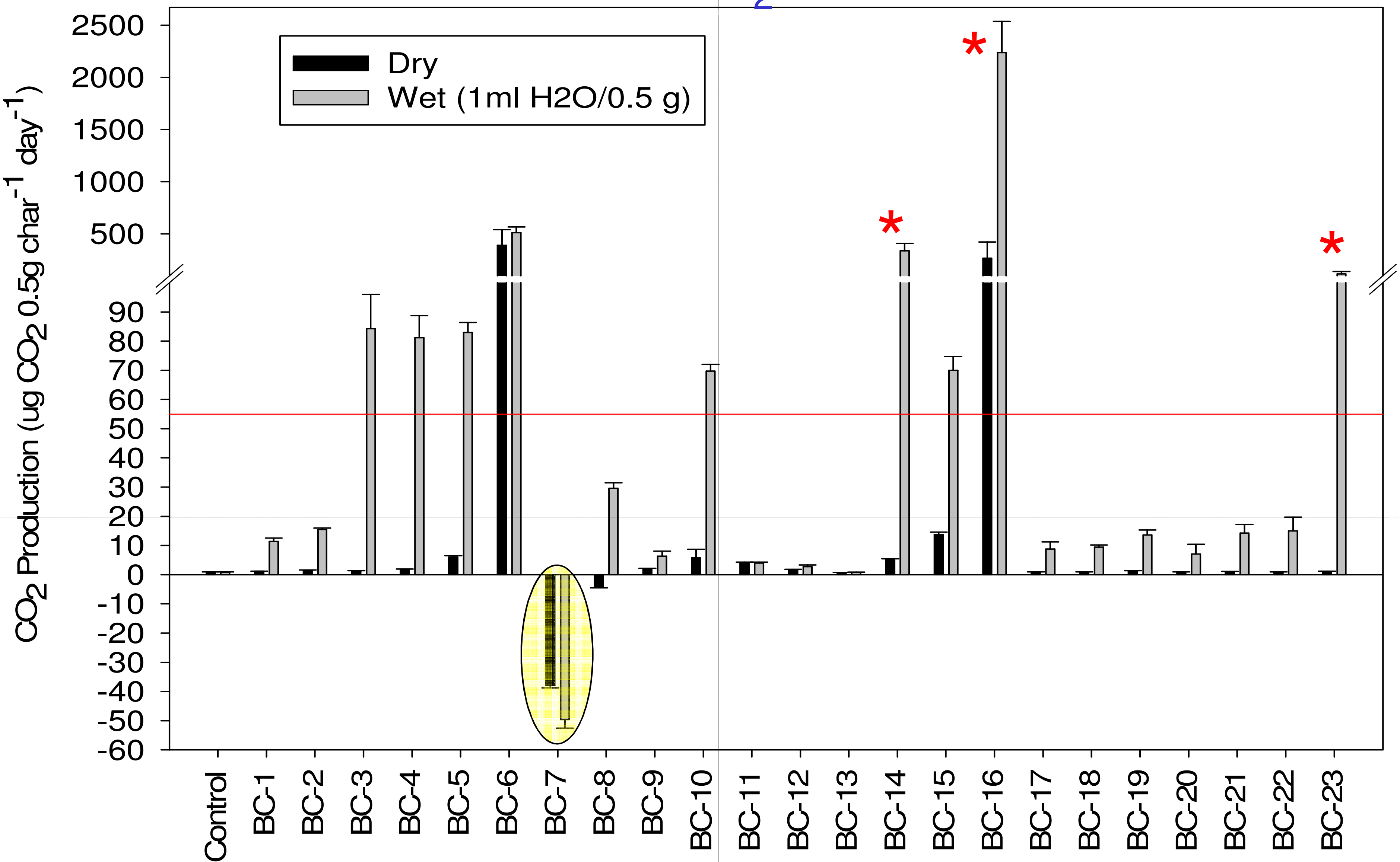
Triplicate Incubation Set-up

Set #	Biochar Amount (g)	Soil	Water (mL)
1	0.5	None	0
2	0.5	None	1.0
3	0.5	Agricultural soil (5g)	0.74
4	0.5	Forest nursery soil (5g)	0.60
5	0.5	Landfill cover soil (5g)	1.24
6	None	Agricultural soil (5g)	0.74
7	None	Forest nursery soil (5g)	0.60
8	None	Landfill cover soil (5g)	1.24
9 (Control)	None	None	1.0

Assessment of Gas Production

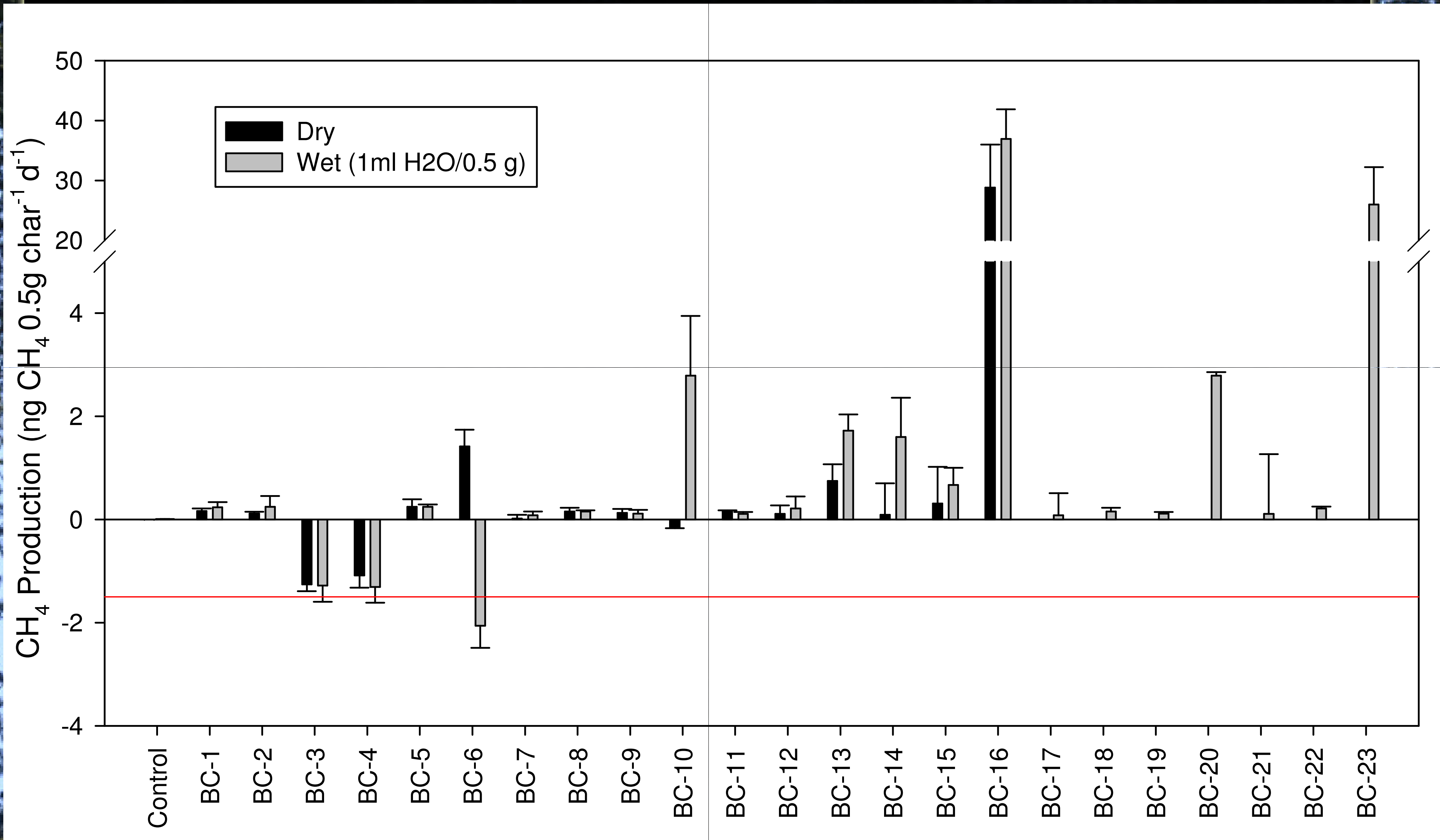
- 5 g of soil mixed with 0.5 g biochar (10% w/w)
- Headspace periodically monitored with GC/MS
- 10 day pre-incubation
- Production rates estimated from the change in concentration with time.
- Length of incubations 25 – 100 days
- Requirement: O_2 concentrations >15%

Biochar CO_2 Production

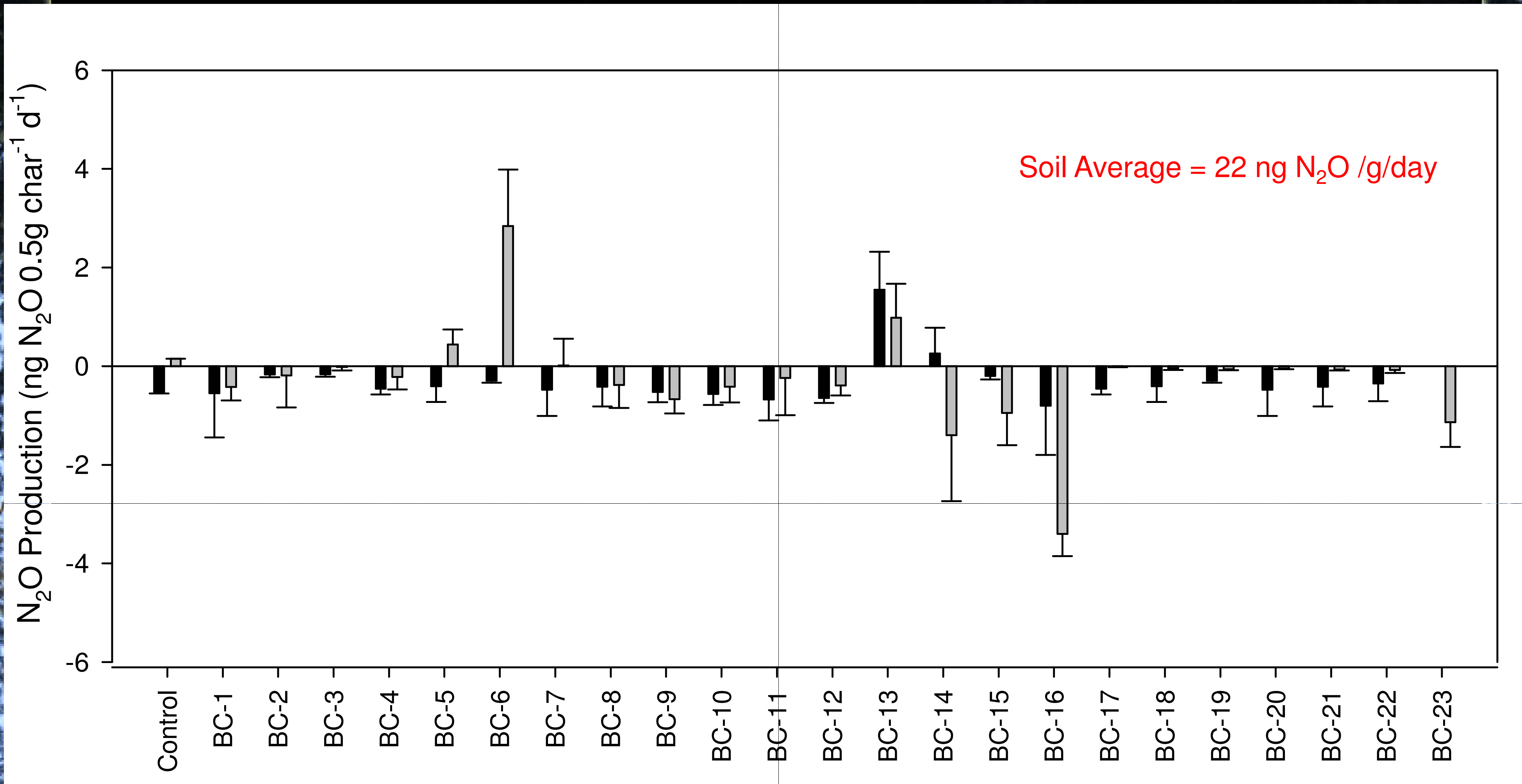


Red line = average soil basal respiration (3 different soils)
9 above and 14 below soil average

Methane : Biochar alone



N_2O : Biochar alone



Only 4 biochars were significantly different than control (no char) – 1 produced N_2O and 3 consumed N_2O (sorption or denitrification?)

Correction for Biochar production

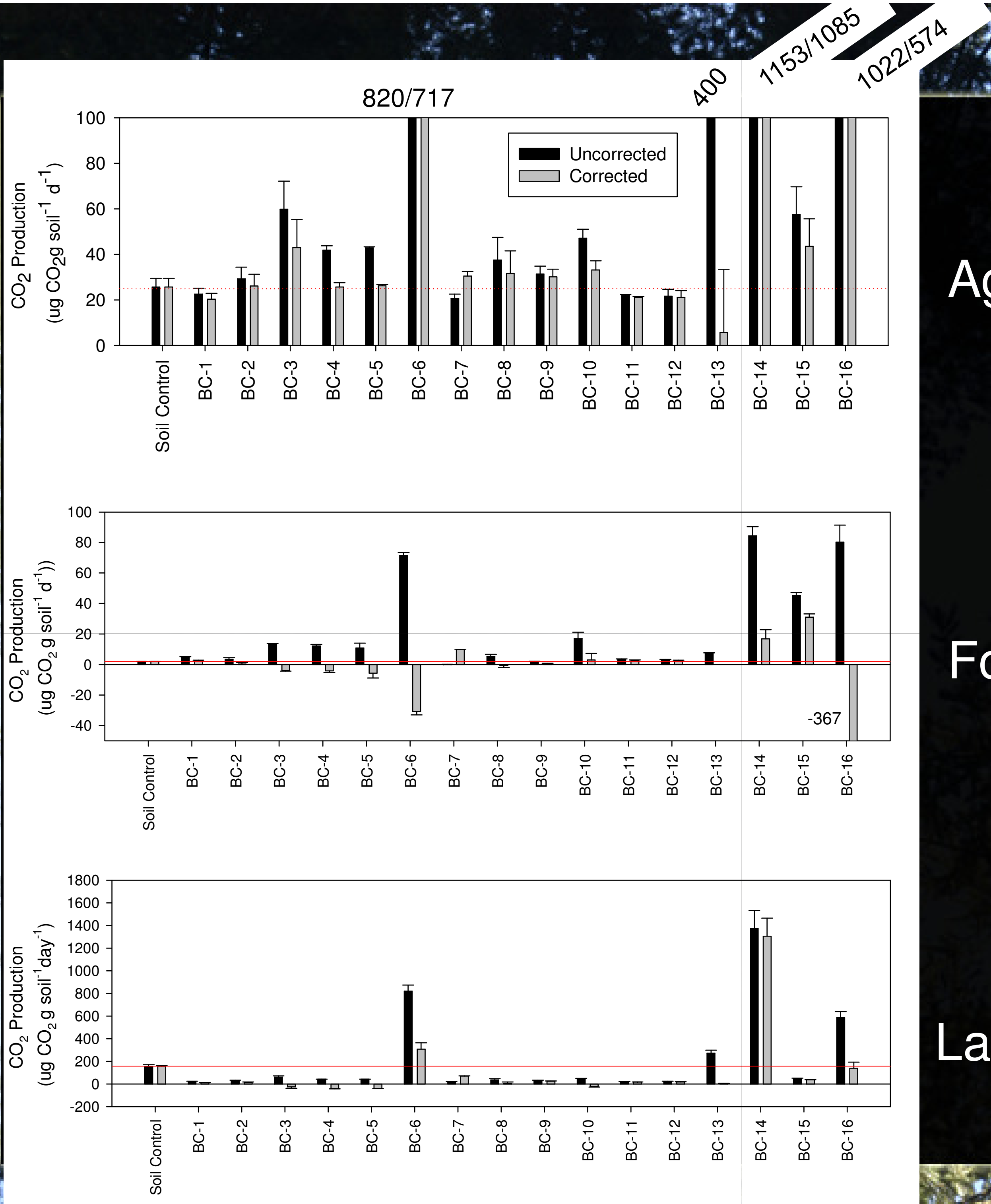
$$\text{CO}_2\text{Production Rate Corrrected} = \frac{\left(CO_2^{\ biochar+soil} - CO_2^{\ biochar}\right)}{5g_{\ soil}(\text{t}_d)},$$

$CO_2^{\ biochar+soil}$ is the total CO_2 production from the soil + biochar + water incubation (μg CO_2) at time t_d

$CO_2^{\ biochar}$ is the total CO_2 production (μg) at time t_d for the biochar + water incubation

t_d is the time of sampling (days)

CO_2

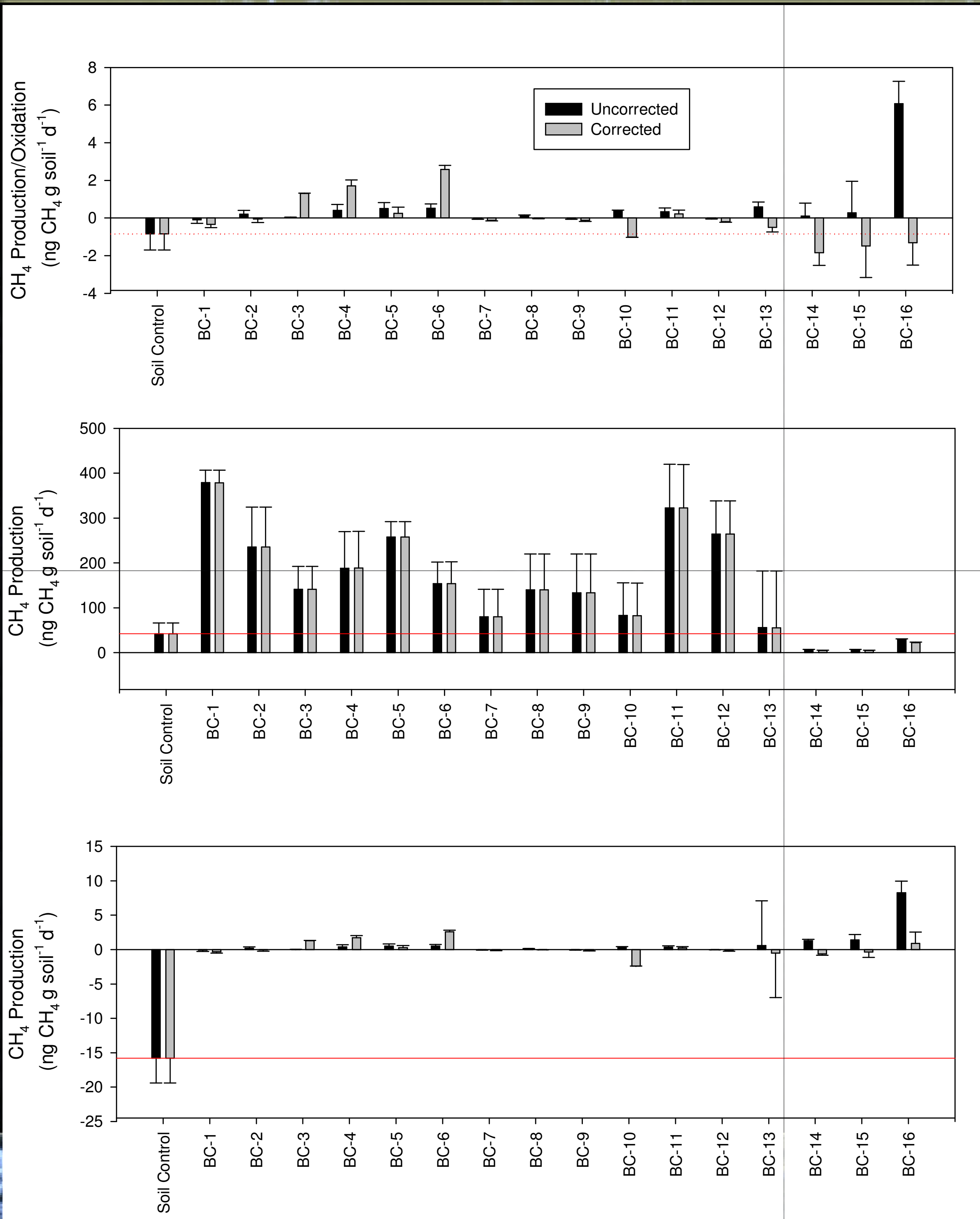


Agricultural Soil

Forest Nursery Soil

Landfill Cover Soil

CH_4

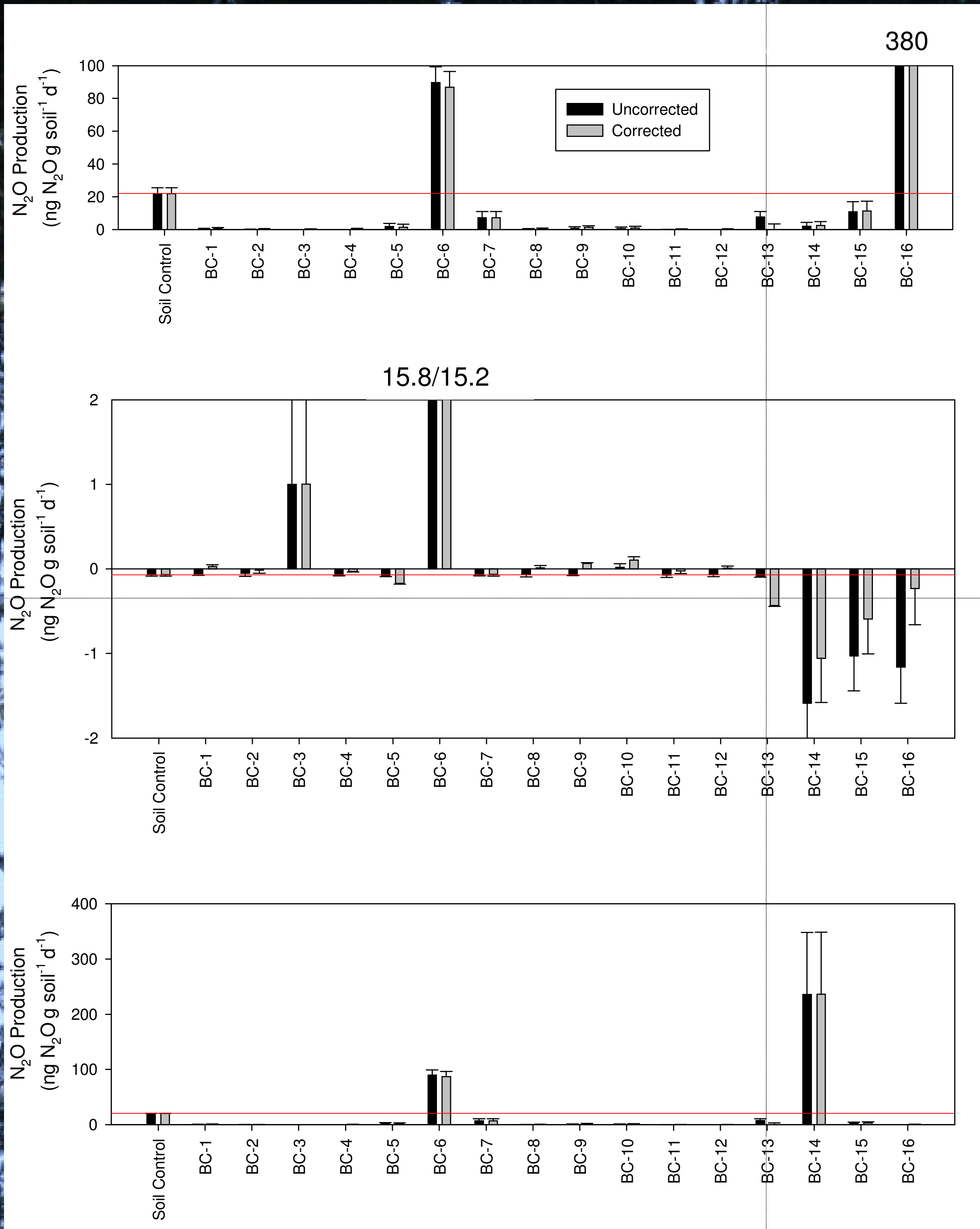


Agricultural Soil

Forest Nursery Soil

Landfill Cover Soil

N_2O

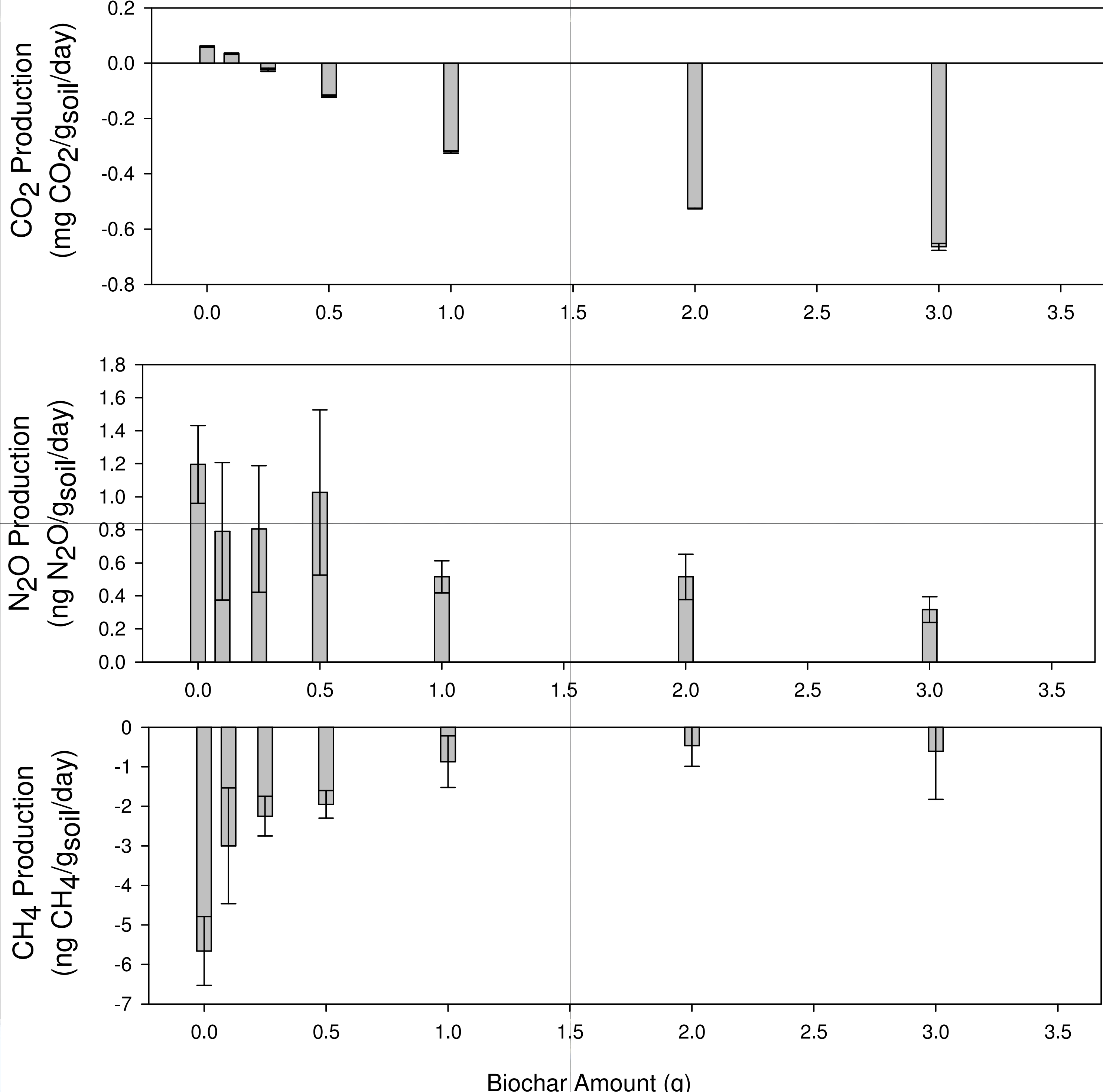


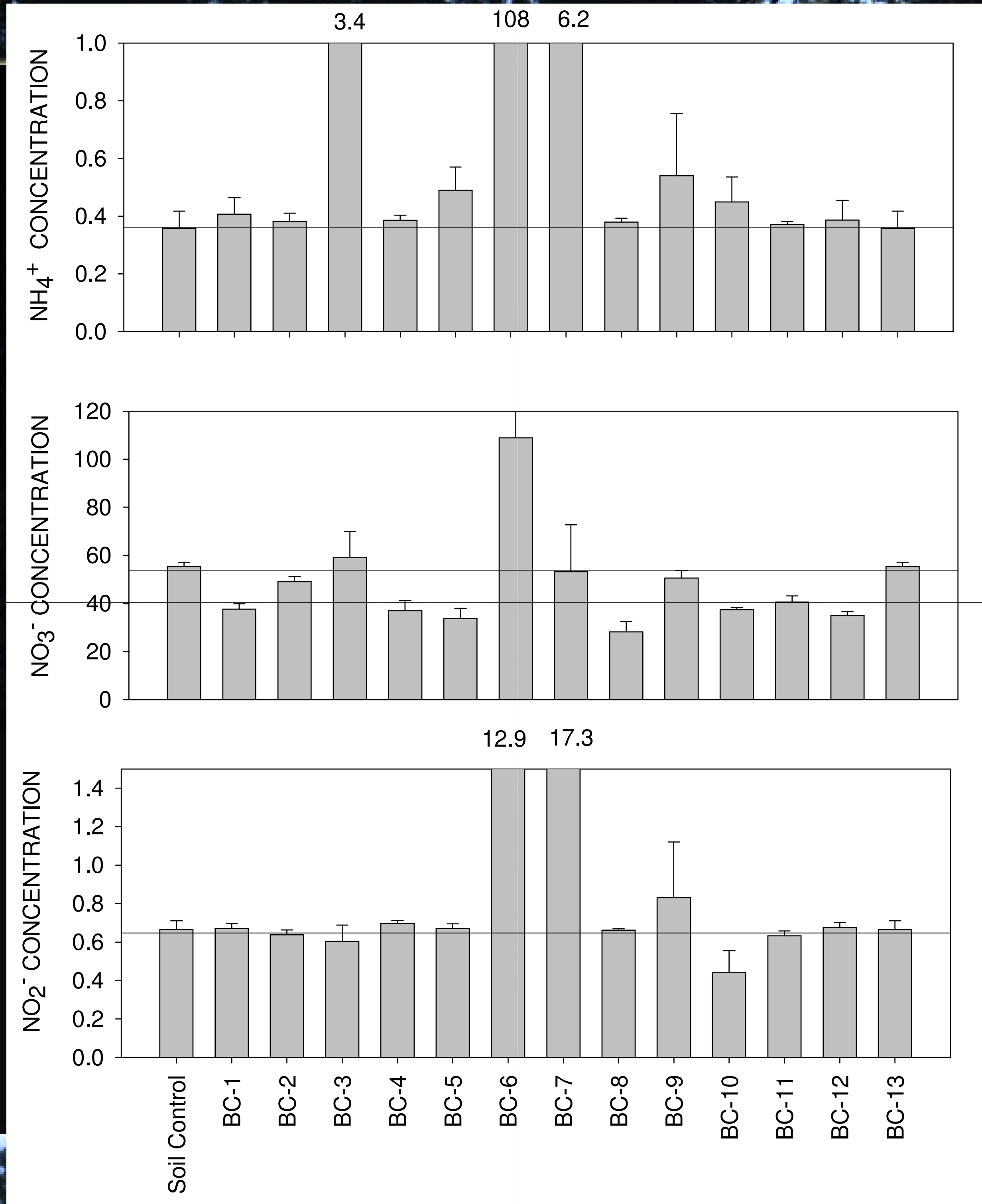
Agricultural Soil

Forest Nursery Soil

Landfill Cover Soil

Influence of biochar amount on GHG Production




3.4
108
6.2
NH4+ CONCENTRATION
1.0
0.8
0.6
0.4
0.2
0.0
NO3- CONCENTRATION
120
100
80
60
40
20
0
12.9
17.3
NO2- CONCENTRATION
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Soil Control
BC-1
BC-2
BC-3
BC-4
BC-5
BC-6
BC-7
BC-8
BC-9
BC-10
BC-11
BC-12
BC-13

Conclusions

- Positive effect observed so far in laboratory
    - Reduction in N_2O production potential

- Besides BC-14; No consistent trends in CO_2 effects across soil types
    - Majority reduced basal CO_2 respiration
    - BC-14 (wood pellet aerobic char) increased CO_2 production across all soils

- Majority of biochars reduced CH_4 oxidation activity
    - Soil methanotrophs are the only known biological sink for atmospheric methane
    - Also reduced methanotroph activity (CH_4 production)

Conclusions

→ Not all biochars are the same:
Creation process, original feedstock, temperatures, etc..

→Greenhouse gas production:
Complicated by biochar production, release, or sorption – this is particularly important for CO_2

→Overall, greenhouse gas impacts function of both <u>char and the soil</u>

Acknowledgements

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Fast pyrloysis char (CQuest™) through non-funded CRADA agreement

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Slow pyrolysis char through a non-funded CRADA agreement

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Biochar Brokers

Chip Energy

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