Use of Biochar from the Pyrolysis of Waste Organic Material as a Soil Amendment

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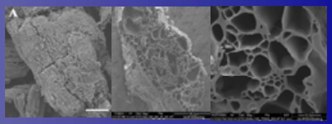
ABSTRACT

Biochar is being promoted for its potential to improve soil properties, fertility and carbon sequestration in soil. How this material might impact agricultural soils within temperate regions is largely unknown, Validation of biochar as a beneficial soil amendment and carbon sink would add important economic value to the pyrolysis process and spur adoption. Bio-chars from five waste feedstocks (pine chips, softwood bark, grass seed straw, peanut hulls, anaerobic digested manure fiber were produced with a pyrolysis unit developed by Washington State University. We evaluated each for their influence on the soil properties; pH, buffering capacity, cation exchange capacity, water retention curves, soil nutrient availability (N, P, K, S, micronutrients) soil biological activity, and C sequestration potentials of five soil types. Activated charcoal was included as a standard analysis and compared to biochars.

Pellets

Chared Pellets 500 °C



Micrographs of Char Boateng, 2008

OBJECTIVE

Determine the effects of biochar additions on soil biological, chemical and physical properties.

MATERIALS AND METHODS

The following methods were used to evaluate the biochars and their influence on soil properties: Total soil organic C and N will be determined by dry combustion on a LECO, CNS-2000 Elemental Analyzer (St. Joseph, MI). The pH of each biochar feedstock and pH of each soil application rate were determined using the 2:1 water method of Robertson et al. (1999). Cation exchange capacity of each biochar and soil application rate were determined by the method of Robertson et al. (1999). Carbon mineralization was used as a measure of soil biological activity and will be determined using the static-incubation method (Zibilske, 1994). Soil samples + biochar feedstock (100-g) at each biochar application rate was adjusted to 70% field capacity in 1 L containers equipped with rubber septa and incubated at 25° C for an average of 225 days. Headspace CO2 was measured weekly by direct injection of gas samples into an infrared gas analyzer (IRGA) (Analytical Development Co. Ltd, type 225- MK3 Hertfordshire, England). Soil N mineralization potentials was determined by incubating seven-sets of 25 g soil samples from each biochar feedstock and biochar + soil application rate treatment in replicate in 1 L containers over 7 weeks at 25 oC, adjusted to 70% of field capacity (determined by pressure plate analyses described above). Incubated soil is extracted at weekly intervals with 75-ml of 2 M KCl, shaken on a rotary shaker for 1 h, then filtered through a Type A/E glass fiber filter (Gelman Sciences Inc, Ann Arbor, MI). The NO3-N and NH4-N in the extracts was determined on an FIA Series auto-analyzer.

RESULTS

Table 1. Selected characteristics of the five soil types used in the laboratory analyses.

Soil Series	Soil Characteristics: Texture	C	N	S	C:N	C:S	pH	CEC
		--------- $g\ kg^{-1}$		---------				$cmol\ kg^{-1}$
Quincy	Sand	4.3 (0.5)†	0.5 (0.1)	0.2 (0.06)	8.6	22	7.1	3.3
Naff	Silt loam	18.5 (0.4)	1.5 (0.1)	0.1 (0.03)	12.3	185	4.5	15.4
Palouse	Silt loam	23.3 (1.1)	1.9 (0.1)	0.2 (0.01)	12.3	117	4.6	16.0
Thatuna	Silt loam	27.5 (1.1)	2.3 (0.1)	0.3 (0.02)	12.0	92	4.6	16.1
Hale	Silt loam	39.4 (0.2)	3.3 (0.1)	0.6 (0.05)	12.0	66	4.6	16.6

†Std. error of mean in parentheses.

Table 2. Selected characteristics of the six biochars (500 °C) used in the laboratory analyses. Activated charcoal included as a standard analysis and comparison to biochars.

Wood	350	735 (2) a	1.2 (0.2) a	0.8 (0.40) a	571	2000	6.0
Pellets	425	761 (4) b	1.1 (0.1) a	0.3 (0.04) a	692	2537	6.7
	500	782 (18) c	1.3 (0.2) a	0.7 (0.36) a	602	1117	7.2
	600	857 (2) d	1.5 (0.8) a	0.2 (0.04) a	571	4285	7.4
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Peanut hull	500	706 (12)	17.4 (0.9)	0.6 (0.1)	41	1178	9.6
Bark-UGA	500	745 (4)	3.4 (0.3)	0.3 (0.1)	219	2483	7.6
Act. Charcoal		873 (3)	4.7 (0.6)	7.6 (0.4)	186	115	9.1

†Std. error of mean in parentheses. Nd –not determined. UGA- the bark was made using a pyrolyzer unit located at the University of Georgia, Athens. Statistical comparisons were not made between biochars. Values for a biochar within a column followed by the same letter are not significantly different at p = 0.05.

- Herbaceous feedstock sources such as switchgrass and anaerobic digested manure had C contents of 60 and 67% respectively, as well as significantly higher N contents then the other biochars.
- Woody feedstocks: bark, soft bark and wood pellets had C contents above 75% with C:N ratios ranging from 176 - 588.

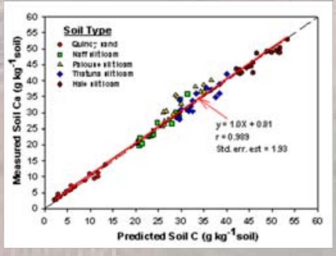
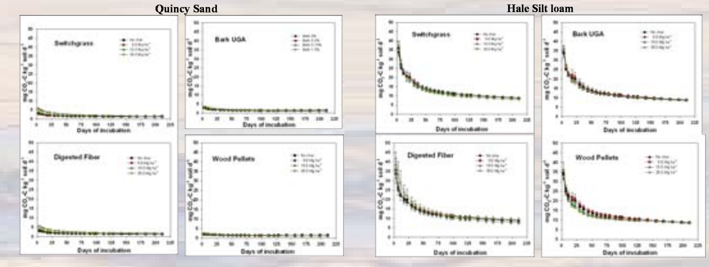


Figure 1. Relationship between predicted soil C in biochar amended soils and the amount of soil C recovered after long-term (200+ d) laboratory incubation.

- C recovery following lab incubations was well correlated to the initial application of biochar C among the various soil types.
- Soil pH was found to increase 1 unit for the highest rate (1.5%) of biochar addition for the herbaceous feedstocks and 0.5-1.0 units for the woody sources.

C-Mineralization

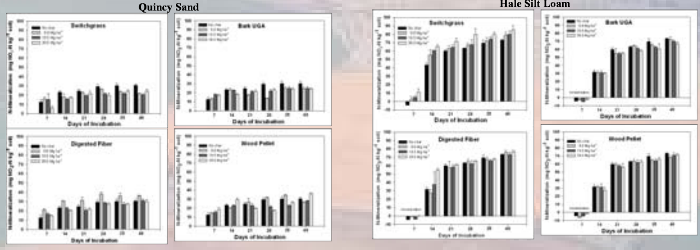
Quincy Sand | Hale Silt loam



- Carbon sequestration potentials of each biochar and soil application rate were determined by long-term laboratory incubations.
- Mineralization among biochars was significantly different only in the initial days of the incubation and can be partly explained by the presence of the hydrolysable C in the biochars. The increase in CO_2 evolved was 1-10 mg CO_2-C / g soil.
- The herbaceous materials (switchgrass and digested fiber) contained 5-6% hydrolysable C and < 0.2% N which may help explain the initial flush of CO2 for these materials during the initial stages of mineralization.
- The non-hydrolysable fraction has been shown to have a mean residence time (MRT) of 100's to 1000's of years.

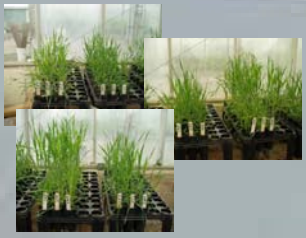
N-Mineralization

Quincy Sand | Hale Silt Loam



- N-mineralization among soil types showed a decrease in nitrate production with increasing rates of biochar addition among some soil types. The decrease was not significant from the no-char treatment.

Green House Trials



- Total plant biomass trended to be greater when amended with biochar. The average increase was 25%.
- We also observed a reduction in growth at the amendment rate of 39 $Mg\ ha^{-1}$.

Table 4. Wheat roots, shoots and Root:shoot ratio after growth in Quincy sand and Hale silt loam soils amended with a variety of biochars.

Soil Series	Biochar	‡Plant Characteristics: †Rate	Root	Shoot	Total	R:S
		$Mg\ ha^{-1}$	--------- g	---------		
Quincy	Peanut Hull	0	2.1	7.7	9.9	0.27
		9.8	1.8	8.2	10.0	0.22
		19.5	1.7	9.5	11.2	0.18
		39.0	1.8	7.8	9.8	0.24
	Soft bark	0	3.3	8.8	12.1	0.38
		9.8	3.1	12.9	16.0	0.24
		19.5	4.1	15.4	19.6	0.26
		39.0	3.0	10.2	13.2	0.29
	Wood pellets	0	14.7	8.3	23.0	
		9.8	14.1	9.7	23.8	
		19.5	10.9	12.5	23.4	
		39.0	11.2	8.2	19.4	
	Act. Charcoal	0	5.9	9.6	15.6	0.62
		9.8	2.2	8.3	10.5	0.27
		19.5	3.3	11.9	15.3	0.28
		39.0	2.3	8.9	11.2	0.26
Hale	Peanut Hull	0	1.6	6.3	8.0	0.26
		9.8	1.7	6.7	8.5	0.26
		19.5	1.7	9.0	10.7	0.19
		39.0	1.6	6.2	7.9	0.26
	Soft bark	0	1.1	11.6	12.8	0.10
		9.8	1.7	11.0	12.7	0.15
		19.5	1.7	14.2	15.9	0.12
		39.0	1.8	12.1	14.0	0.15
	Wood pellets	0	10.1	7.3	17.4	
		9.8	9.4	6.3	15.6	
		19.5	11.4	7.5	18.9	
		39.0	9.6	5.3	14.9	
	Act. Charcoal	0	2.4	7.5	9.9	0.32
		9.8	2.3	7.5	9.9	0.32
		19.5	1.9	9.1	11.1	0.22
		39.0	1.7	6.9	8.6	0.25

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