Phosphorus Sorption Behavior in Biochar-amended Soils

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Introduction

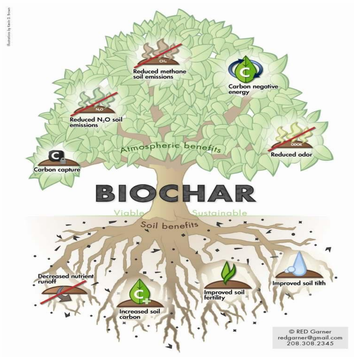


Fig. 1: Applications of Biochar
Source: http://www.coaltecenergy.com/wp-content/uploads/2012/05/biochar.jpg

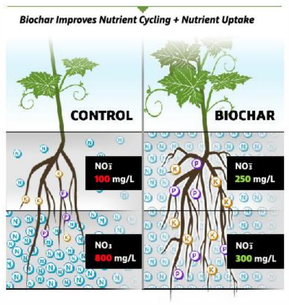


Fig. 2:Improved nutrient management in Biochar amended soil
Source : http://www.coolplanet.com/biocharviticulture

- Biochar is a byproduct obtained from the pyrolysis of biomass at very high temperature in the absence of oxygen.
- Potential benefits from biochar application include soil fertility (Fig.1) and reduced soil-nutrient loss (Fig. 2).
- Site-specific information is not available on the optimum amount of biochar that needs to be applied to support plant growth and prevent phosphorus (P) losses from soil.

Hypotheses

- Phosphorus retention is a property of the soil; biochar additions may not necessarily contribute to P retention at environmentally relevant solution P concentrations.
- Biochar addition to sandy or clayey-loam soils may cause considerable variations in P retention and release.

Objectives

- To determine the effects of commercially available hardwood biochar (HWB) from the USA (HWB 1) and India (HWB 2) added at 2% percent rate (w/w), on P sorption and release to: i) three manure-impacted sandy soils from Florida, USA and ii) three agricultural soils from Karnataka, India.

Study Sites

- Three sites were chosen from an agroforestry (AF) farm in Karnataka, India: 1) coffee plantation, 2) bamboo AF system and 3). a native forest (Fig. 3).

- Three manure impacted soils from dairy farms in the Suwannee River Basin of Florida, USA (Fig. 4).

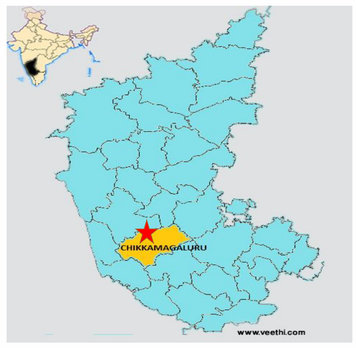


Fig. 3. Koppa plantation area, Karnataka, India
Source: http://www.kamat.com/kalranga/kar/dists.htm

Fig. 4. Suwanee river basin, FL, USA
Source: http://pubs.usgs.gov/fs/FS-010-99/html/fig01.html

Acknowledgement

The authors thank Willie Harris for his helpful comments during various stages of this work and for his assistance with X-ray diffraction analysis.

Materials and Methods

Experimental Design

1. Soil

- **Soils from a coffee based Agroforestry system in Karnataka, India. Sites 1,2 & 3.**
- **Manure Impacted soils from Florida, USA Sites 4,5 & 6**

2. Hardwood biochar (HWB 1 and HWB 2) applied at 2 % (w/w)

HWB 1 for Florida soils (Sites 4,5 & 6).

HWB 2 for Karnataka soils (Sites 1,2 & 3).

3. Soil:Biochar

Eleven concentrations of external P ranging from 0 to 1000 (mg kg $^{-1}$) were added.

P concentrations (mg kg $^{-1}$): 0, 0.1, 1, 10, 50, 75, 100, 250, 500,1000

14 days incubation (For soil + HWB only. Incubation is not required for soil without biochar)

(Solid: Solution =1:10)

Mechanical shaking

Equilibration 24h

Filtration

Analysis

Equilibrium P concentration (EPC_0)

X Ray Diffraction of HWB 1 and HWB 2 (With and without P incubation)

Desorption : Studies conducted on commercially-available HWB sample at the highest rate of P addition (1000 mg kg $^{-1}$).

C/S = 1/K S max + C/S max
C= Concentration of P after 24 h equilibration, mg L $^{-1}$
S_{max} = P sorption maximum (mg kg $^{-1}$)
K= A constant related to bonding energy, L mg $^{-1}$ P

Soil Analyses & Calculations

- Equilibrium P concentrations (EPC_0) in the solution (after 24 h shaking) were calculated for six biochar-amended soils and six soil samples without added biochar.
- A desorption study was conducted on HWB 1 at the highest rate of P addition (1000 mg kg $^{-1}$).
- X ray diffractions were carried out for the hardwood biochar samples with and without P incubation.

Results and Discussions

Table 1: EPC_0 values of soil and biochar amended soil samples. Sites 1,2,3: Karnataka, India; Sites 4,5,6: Florida , USA

Location	Site Number	EPC_0 (Soil) mg L $^{-1}$	EPC_0 (Soil + 2% HWB) mg L $^{-1}$
Karnataka India	1	0.48	0.04
	2	0.06	0.10
	3	0.01	0.14
Florida USA	4	3.06	0.93
	5	2.30	0.90
	6	0.38	0.14

The EPC_0 of HWB 1 and HWB 2 were 4.23 mg L $^{-1}$ and 3.8 mg L $^{-1}$, respectively.

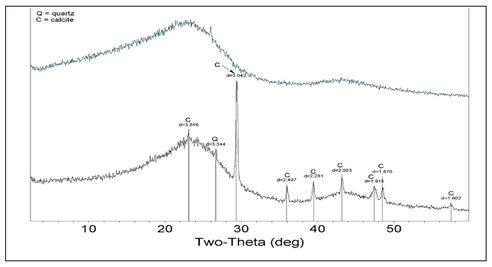
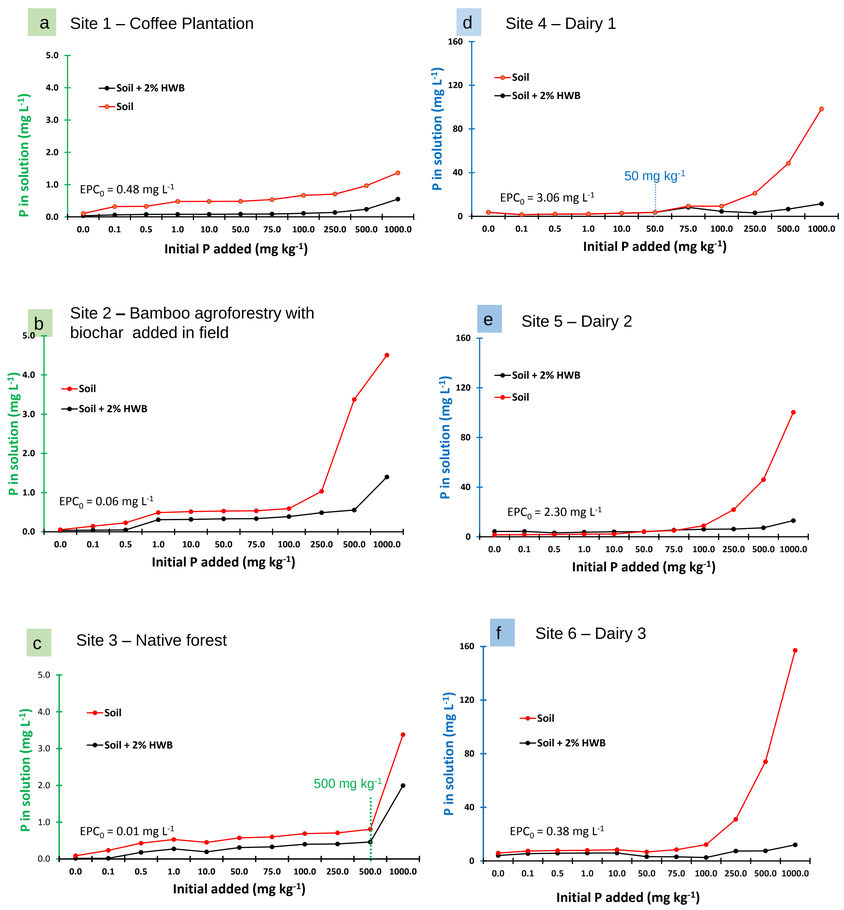


Fig. 4:X-ray diffraction analysis of HWB 1before (lower) and after P addition (upper) showing mostly calcite and quartz peaks.

Karnataka, India **Florida, USA**



Figs. 5 (a – f) : P added vs. P in soil solution at equilibrium.
Note: The P in solution (mg L $^{-1}$) (y axes) differences are substantial between soils from plantation sites in Karnataka, India and dairy farms in Florida, USA.

- At lower concentrations of added P, difference in solution P was minimal for soil and biochar-amended soils.
- The P in solution showed a maximum of 145 mg L $^{-1}$ for sandy Florida soils and 4.5 mg L $^{-1}$ for clayey loam soils (Figs. 5 a – f).
- The inflection point is identical for the forest soil with and without biochar additions – minimally P impacted (Site 3).
- Rapid increase in P concentrations occurs between 50 &100 mg kg $^{-1}$ for Florida sandy soils (depending on the P impact level) and at ~ 500 mg kg $^{-1}$ for clayey-loam Karnataka soils (Figs. 5a – f). *Note y-axes differences in the graphs.*
- Sequential desorption showed continued P release from HWB 1: 16% in the first extraction, 11% in the second extraction, and 4.5% in the 3rd extraction suggesting that P held by biochar is of temporary nature and will be released into the soil when in contact with water.
- Further X-ray diffraction analysis of HWB 1 showed calcite and quartz peaks with no metal-P association even with high additions of P (Fig. 4). X-ray diffraction of HWB 2 showed identical results with calcite and quartz peaks.

Conclusions

- P retention at environmentally relevant P concentrations depends on soil properties and not biochar properties.
- Biochar application reduces P in solution for all soils. However, the P is weakly held by the biochar and therefore available for crop uptake.
- Field application of biochar should be determined according to site-specific conditions. The amount of biochar that can be added “safely” to a soil before it becomes an environmental issue depends on the soil type and its P application history.