Hardwood and Poultry Litter Biochar Effects on Phosphorus Sorption in Soil

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1 Introduction

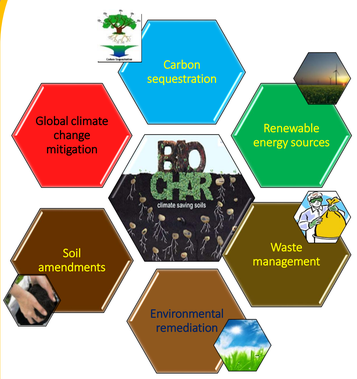


Fig. 1: Multifunctionality of biochar

Fig. 2: Flow chart showing nutrient release & retention by biochar

- Multifaceted benefits of bichar (Fig. 1) includes sequestration of nutrients in environment (Fig. 2).
- Land application of biochar enhances P availability to plants.
- Amount of biochar needed to prevent P losses from soil on site-specific basis is lacking (Fig. 2).
- Threshold phosphorus saturation ratio (PSR), can be calculated from P, Fe & Al in a soil test solution such as Mehlich 3.
- Soil P storage capacity (SPSC), calculated based on a threshold PSR (Fig. 3) value, is a measure of the amount of P a soil can hold prior to becoming an environmental risk.

2 Hypothesis

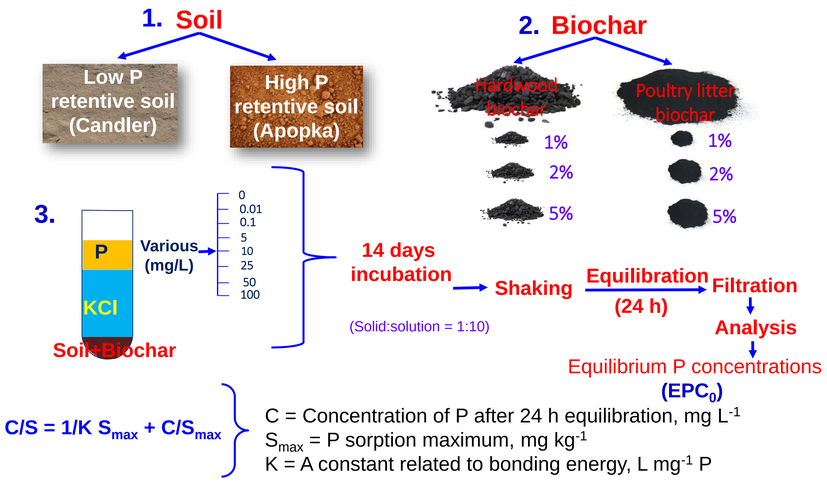
- P retention is a property of the soil and biochar additions will not contribute to P retention at environmentally-relevant solution P concentrations.

3 Objective

- To determine the effects of commercially available hardwood biochar (HWB) and poultry litter biochar (PLB) added at different rates on P sorption and release from soils with different P retention capacities .

4 Materials and Methods

Experimental Design



$C/S = 1/K\ S_{max} + C/S_{max}$

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

Acknowledgments

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Materials & Methods

Soil Chemical Analyses & Calculation

- pH & EC were determined for soils, biochars & soil/biochar mixtures.
- Mehlich 3- P, Fe, Al (M3-P, Fe & Al) were determined for soils on Inductively Coupled Atomic Spectrophotometer (ICP).
- Equilibrium P concentrations (EPC_0) in solution (after 24 h shaking) were analyzed for all soil & soil/ biochar mixtures.

PSR (Nair et al., 2004) and SPSC (Nair and Harris, 2004)

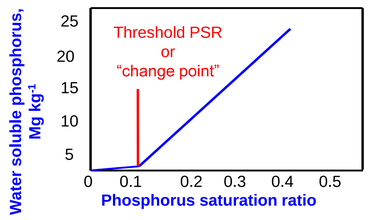


Fig. 3: Relationship between WSP & PSR

PSR = Ex-P/ [ExFe + ExAl]
Ex = Oxalate, Mehlich 1 or Mehlich 3

Threshold PSR = 0.1

$$SPSC = (0.1 - \text{Soil PSR}) * \left[\frac{\text{Mehlich 3Fe}}{56} + \frac{\text{Mehlich 3Al}}{27}\right] * 31 \quad (\text{mg P kg}^{-1})$$

$SPSC_{Candler}$ = 45 mg kg^{-1}

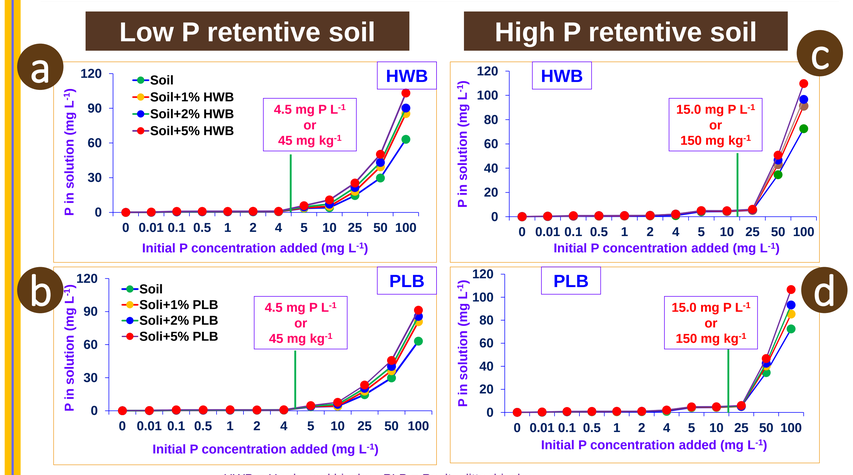
$SPSC_{Apopka}$ = 150 mg kg^{-1}

5 Results and Discussions

Table 1: Characteristics of soils & biochars

Soils	pH	EPC_0 mg L^{-1}	P	Fe	Al	Smax mg kg^{-1}
			-------mg kg^{-1}----------			
Candler	5.5	0.30	15	113	469	120
Apopka	4.8	0.20	31	436	1380	202

Biochars	Pyrolysis Temp (°C)	pH	EC dSm^{-1}	TP mg kg^{-1}	EPC_0 mg L^{-1}	Smax mg kg^{-1}	Langmuir K L mg^{-1}
HWB (#)	500	9.6	443	1,898	4.23	289	0.01
PLB ($)	400	10.5	489	25,615	2.75	444	0.02



HWB = Hard wood biochar; PLB = Poultry litter biochar

Fig. 4: Initial P concentration added & P in soil solution for mixture of low P retentive soil & biochars [(a) HWB (b) PLB] & high P retentive soil & biochars [(c) HWB & PLB (d)]

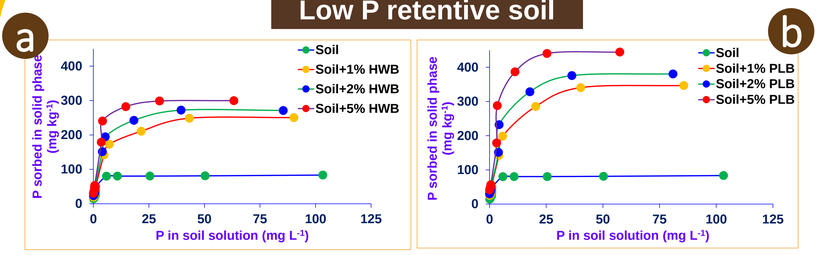
- After a certain limit (~45 mg kg^{-1} for Candler and 150 mg kg^{-1} for Apopka) of P addition, P began to be released from soil under all treatments irrespective of biochar nature (Fig. 4 a, b, c and d).

Reference

- Nair V D, K M Portier, D A Graetz, and M L Walker, 2004. An environmental threshold for degree of phosphorus saturation in sandy soils. J. Environ. Qual. 33:107-113.
- Nair V D and W G Harris, 2004. A capacity factor as an alternative to soil test phosphorus in phosphorus risk assessment. New Zealand J. Agric. Res. 4:491-497.

Results and Discussions

Low P retentive soil



HWB = Hard wood biochar; PLB = Poultry litter biochar

Fig. 5: P in solution & P sorbed in solid phase for low P-retentive soil and biochars [(a) HWB & (b) PLB] mixtures [Only results for low P-retentive soil is shown here; similar behavior for high P-retentive soil]

- Both HWB & PLB have higher S_{max}, compared to soils (Fig. 5 a & b).
- Maximum P retention capacity of soils (S_{max}) increases with increases in biochar addition which might be an analytical artifact (due to higher moisture holding capacity) of biochar (Fig. 5 a & b).

6 Conclusions

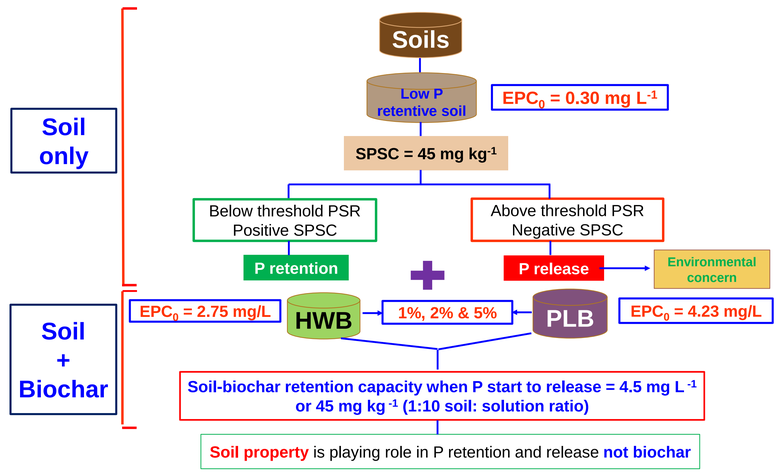


Fig. 6: Illustration of effect of biochar addition to soil taking the low P-retentive soil as example

- When EPC_0 of biochar is greater than that of soil, biochar will release P to soil (Table 1 and Fig. 6).
- Irrespective of nature of biochar, P retention at environmentally relevant P concentrations is based on soil properties (i.e, SPSC) & not of biochar.
- Soil will retain P as long as the P released by biochar is less than which can be accumulated by soil below threshold P saturation ratio.
- If two minimally P-impacted soils are treated with identical amounts of a given biochar, amount of biochar that can safely be added to soils will be a function of SPSC.
- Point of P release can be calculated from the SPSC equation i.e., amount of P that can be added to soil to bring SPSC to "zero" (until the threshold PSR is reached).

7 Take Home Message

- Biochar can be a P source rather than sink when applied to minimally P-impacted sandy soils.
- Biochar reduction of P loss from soil requires that it has a lower EPC_0 than soil.
- While biochar is able to retain more P (i.e., contribute to S_{max}), P retention & release from a biochar-amended soil is a property of the soil at environmentally-relevant solution P concentrations.
- Long-term effects of biochar addition will result in release of P once soil's threshold PSR is reached (SPSC becomes negative).