EFFECTS OF CHARCOAL AND ORGANIC FERTILIZER ON PHOSPORUS ADSORPTION AND BIOAVAILABILITY IN SOILS OF THE CENTRAL AMAZON

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INTRODUCTION

The utility of charcoal as a nutrient management tool is partially based on its sorption and exchange properties for plant nutrients. The cation exchange properties and ammonium fixation potential of charcoal sources have long been identified (Batnaga 1965, 1966). However, the P sorption and P release characteristics of biochar are still undocumented, even though there has been an increasing interest in Terra Preta do Índio (Dark Earth Soils). The nutrient management properties of charcoal are central to understanding the acknowledged influence of biochar on nutrient leaching and fertilizer efficiency (Oguntunde et al. 2004, Topoliantz et al. 2005, Yamato et al. 2006, Steiner et al. 2007). The two objectives of this series of studies were to (1) investigate the P adsorptive capacity and the nutrient bioavailability of different sources of wood and temperatures of carbonization; (2) study the use of charcoal in remediation of degraded soils under both greenhouse and field environments.

METHODOLOGY

This research was developed in three steps. The first one was in laboratory as pyrolysis of tree species (Ingá, Imbaúba and Lacre) and three combustion temperatures (400, 600 and 800º C) accomplished as a 3 x 3 factorial arrangement with five replication. In all samples were measured extractable macro and micronutrients levels phosphorus adsorption isotherm.

The second was a greenhouse experiments was developed as factorial 5 x 5 arrangement of five levels of charcoal powder and five levels of cow manure. The specie was faveira seedling (*Enterolobium cyclocarpum* (Jacq.) Griseb. The soil was an Oxisol and specie used for charcoal production was (*Vismia guianensis*), at 600 celcius degree carbonization temperature.

The third one was a field experiment arranged as factorial design with five treatments (T1: control, T2: nature phosphate, T3: nature phosphate plus charcoal powder, T4: nature phosphate plus organic compost, T5: nature phosphate plus charcoal powder plus organic compost and 3 replication. The soil is a Cambissolo Háplico distrófico and the specie was lacre *V.guianensis*

RESULTS AND DISCUSSION

Experiment I. If biochar is to be used as a soil amendment, the extractability of its nutrient content describes its potential as a fertilizer material for nutrients that do not volatilize at the temperatures of carbonization and may provide an early indicator of any toxicity problems that could track the use charcoal. The average coefficient of variation of the 5 replicates for extractable nutrients was 7% (P), 11% (Fe), 12% (Zn), 4% (Mn), 40% (Cu) and 4% (K). The resulting analysis of variance indicated a complicated pattern of extractable nutrients with a strong interaction between temperature and tree species for each nutrient (p< 0.01 for all nutrients). Because of the generally high precision of the replicates, the vast majority of nutrient contents in the biochars were determined to be significantly different (Figure 1).

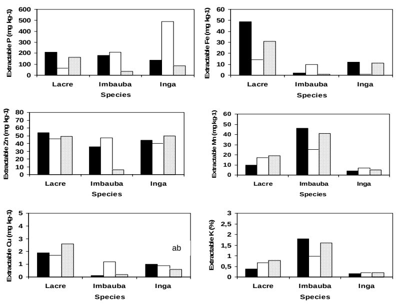

Figure 1. Mehlich extractable P, K, Fe, Mn, Zn and Cu from the charcoal formed from three native pioneer species of the central Amazon region of Brazil. Lacre, Ingá and Imbaúba are the three pioneer tree species. The bars represent the pyrolysis temperatures: the solid black bar is 4000C, the clear bar is 6000C and the stippled bar is 8000C.

Charcoal in Terra Preta, or charcoal made from native wood species today, is not necessarily formed at these high temperatures so their P sorption characteristics are not well documented. These data (Figure 3) show that both Terra Preta charcoal (>2mm) and charcoal made from native species between 400 and 800 C (< 2mm) can be variable; yet all materials have significant P sorption capacity. P sorption onto charcoal from Lacre and Ingá was similar for all three combustion temperatures, both species produced P sorption isotherms that were not statistically different from the charcoal found in Terra Preta at Jiquitiaia.

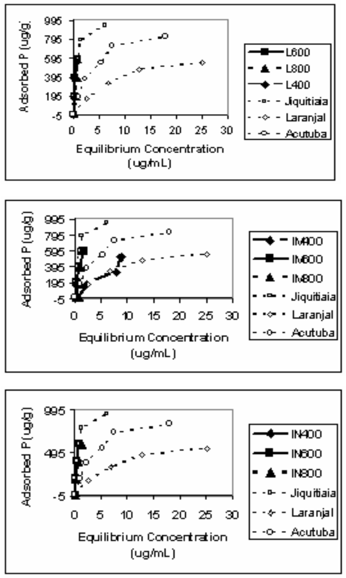

Figure 2. P sorption isotherms for three pioneer Amazonian tree species carbonized at three temperatures and then ground to pass a 2mm sieve. Included in each graph are the isotherms for the charcoal from the tree Terra Preta soils where the charcoal was >2mm diameter. The letters in the legends stand for the tree species (L=Lacre; IM = Imbaúba; IN = Ingá) and the numbers stand for the pyrolysis temperatures in degrees centrigrade.

Experiment II. When charcoal was added to soil in a greenhouse environment, seedlings of the tropical tree species, Enterolobium cyclocarpum, there was no effect on seedling biomass; however the soil had increased exchangeable K, decreased exchangeable Al and greatly increased soil pH (Figure 3). If biochar is to be used as a soil amendment, the extractability of its nutrient content describes its potential as a fertilizer material for nutrients that do not volatilize at the temperatures of carbonization and may provide an early indicator of any toxicity problems that could track the use charcoal.

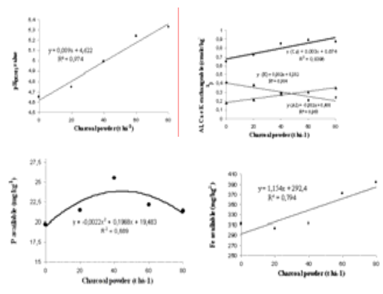

Figure 3. Effect of diferents levels of charcoal powder on soil pH, available phosphorus, aluminium, iron, calcium and potassium exchangeable.

The lower pH value of 4.7 was found for control treatment and the higher value (5.0) was found on treatment 4 that received a combination of organic compost plus nature phosphate. These results revealed an extremely acidy soil condition, characteristic of the most soil unit found in Amazon region (Vieira, 1975; Sanchez, 1979; Vieira, 1988). Some factors can be contributing for that acidity index like for instance: the picked up of the A, B and part of C horizon and also the strong rain during the wet season leading for high loose of base cations (Ca, Mg and K) by leaching, leaving the soil with much more Al and H in the exchange complex then base.

The results presented statistic differences in soil available P. The higher value of available P was found on treatment 4 (nature phosphate plus organic compost) and the lower in the control treatment. The value of available P content, extracted by Mehlich 1, for Brazilian very clayed soil ranged from 6.0 to 10.0 mg kg-1. Havlin *et al.*, (2005) mentioned that soil solution P concentration required by most plants varies from 0.003 to 0.3 mg kg-1.

Charcoal was found to adsorb P, with the adsorption capacity generally decreasing with temperature of carbonization. When charcoal was used in the planting hole of a degraded soil cleared for soil exploration along with rock phosphate, the P levels in the leaves of Vismia guianensis (Lacre) were unaffected by the presence of rock phosphate (Table 2). On the other hand, when charcoal was applied with nature phosphate and organic compost was observed a few decrease on soil P available (Table 1). In terms of plant growing the table 3 are showing that the mixture of nature phosphate with organic compost and charcoal powder allowed a grow increment of more 300% compared with the control plot (Table 3).

Table 1. Soil chemical characterisitc (0-20 cm depth) eighteen months after experiment instalation

	Prof	pH	P	K+	Ca++	Mg++	Al
	cm	H2O	mg/kg	Cmolc/kg			
T1	0-20	4,9	0,3 a	0,22	1,69	0,24	3,73
T2	0-20	4,9	1,2 ac	0,08	1,22	0,09	4,1
T3	0-20	4,7	1,1 ac	0,10	1,47	0,14	3,46
T4	0-20	4,9	5,4 b	0,11	2,01	0,12	3,43
T5	0-20	5,0	4,3 bc	0,10	1,62	0,09	3,55

Mean followed by the same letter do not differ by Tukey test at 5%

Table 2. Foliar nutrients concentration on Lacre (Vismia guianensis) eighteen months after planting

Treatmen	Macronutrient (g kg^{-1})				Micronutrient (mg kg^{-1})		
	Ca	Mg	K	P	Fe	Zn	Mn
T1	6,34	1,11 a	5,78	0,871 a	143,5 ab	18,5	21,2
T2	7,57	1,27 ab	5,77	1,219 a	124,9 ab	19,8	22,9
T3	6,19	1,43 bc	5,92	1,313 a	95,5 a	19,5	20,8
T4	7,12	1,43 bc	5,17	2,949 b	147,6 ab	24,0	16,5
T5	6,70	1,47 bc	5,9	2,532 b	147,6 ab	24,8	19,4

Mean followed by the same letter do not differ by Tukey test at 5%

Table 3. Dry matter weigh of leaves (LDM); stems (SDM), trunk (TDM) and total dry matter (TDM)

Treat.	LDM	SDM	TDM	Total dry matter
	(g)	(g)	(g)	(g)
T1	51,13 a	46,66 a	72,78 a	170,58 a
T2	82,94 ab	74,07 a	122,93 ab	279,94 ab
T3	91,88 ab	68,51 a	124,76 ab	285,16 ab
T4	131,81 bc	101,15 a	105,33 ac	338,30 ab
T5	161,72 c	116,43 a	239,30 b	517,46 b

Mean followed by the same letter do not differ by Tukey test at 5%

Table 4. Efect of charcoal powder and organic compost on total dry matter of faveira (Enterolobium barnebianum) with six months after seedling

Cow Manure	Charcoal powder (t $há^{-1}$)					Average
(t $há^{-1}$)	0	20	40	60	80	
0	2,04 AB	2,47 A	2,03 A	1,88 AB	1,62 A	2,01 A
10	1,65 ab B	2,75 a	1,46 b A	2,31 ab	1,60 ab A	1,95 A
20	2,04 abc	3,03 a	1,86 bc	2,83 ab A	1,45 c A	2,24 A
30	**3,08 a A**	2,59 a	1,92 ab	2,05 ab	1,36 b A	2,20 A
40	2,70 a AB	2,68 a	2,03 ab	1,49 b B	1,46 b A	2,07 A
Average	2,30 ab	2,70 a	1,86 bc	2,11 b	1,50 c	

Mean followed by the same capital letter in colum and small letter in the line do not differ by Tukey test at 5%

CONCLUSIONS

The biochar yield of three common pioneer tree species was approximately 25% of the initial dry weight with significant extractable nutrient concentrations of P, K and micronutrients.

The concentrations did not indicate any potential concern over toxicity of these elements to plant production. More importantly, biochars formed under a range of temperature far below the temperatures used to produce activated charcoal were shown to be efficient P sorbers.

There was no evidence that the pyrolysis temperature was a significant control in the P sorption of Lacre and Ingá, while Imbaúba did produce bichar of lower P sorption ability at 400 0C than at temperatures 600 0C and above.

The use of biochar to enhance soil nutrient bioavailability is a worthy objective, but will require more detailed information to adequately explain soil nutrient bioavailability observations of biochar incorporation into soils.

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