POTENTIAL FOR PYROLYSIS CHAR TO AFFECT SOIL MOISTURE AND NUTRIENT STATUS OF A LOAMY SAND SOIL

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Abstract. Pyrolysis of biomass for hydrogen fuel and bio-oil produces a char byproduct. There is evidence that land application of char may increase soil water holding capacity and the ability of the soil to retain nutrients. Increases in these soil characteristics could be beneficial to plant growth as well as improving water quality. Chars produced under different conditions and from different feedstocks have different characteristics. Of the common feedstocks tested, peanut hull char contained higher nutrients and had a higher cation exchange capacity than pine chip, pine bark, or hardwood chip chars. Preliminary moisture release curve data from a Tifton loamy sand indicated moisture holding capacity may be increased at very high rates of char addition. Soil moisture was periodically measured during the growing season in a field study of microplots amended with peanut hull and pine chip pellet char. Although the average soil water content of the plots amended at 22 Mg ha^{-1} was higher than the control, differences in volumetric water content were only significant on one date.

INTRODUCTION

Pyrolysis of biomass for hydrogen fuel and bio-oil produces a char byproduct. There is evidence that land application of char may increase soil water holding capacity and the ability of the soil to retain nutrients (Tryon, 1948; Glaser et al., 2002). Increases in these soil characteristics could improve water quality in agricultural systems. We have begun a number of studies to evaluate the ability of various chars to increase the water and nutrient holding capacity of loamy sand soil.

METHODS

Chars made from peanut hull pellets (PN), pine chip pellets (PC), pine sawdust (SD), pine bark (PB), and hardwood chips (HW) pyrolyzed at 380, 400, and 420 ^{o}C with steam were analyzed for total carbon (C) and nitrogen (N) (LECO CNS-2000 St. Joseph, MI). Nutrients were extracted with Mehlich I solution and measured on a Thermo Jarrell-Ash model 61E ICP. Cation exchange capacity (CEC) was determined by the Na-acetate/ethanol/ NH_4-acetate replacement method. Prior to analysis, samples were leached with deionized water to remove soluble salts. Sodium was analyzed by atomic adsorption on a Perkin Elmer PE 4100ZL. In addition, Tifton soils (fine-loamy, kaolinitic, thermic, Plinthic Kandiudults) were amended with 11 and 22 Mg ha^{-1} PN and PC char in the laboratory. Cation exchange capacity was measured before and after amendment as specified above.

Moisture release curves were determined at 0, 0.02, 0.05, 0.08, and 0.1 MPa for repacked Tifton soils amended with PN or PC char at 0, 11, 22, and 88 Mg ha^{-1} equivalent rates. Four replicate curves were determined.

A field study of corn (*Zea mays*) growth response in microplots (1.8 x 2.2 m) amended with PN and PC char produced at 400^{o} C was conducted in Tifton. Treatments were control, fertilizer check, PN 11Mg ha^{-1}, PN 22 Mg ha^{-1}, PC 11 Mg ha^{-1}, PC 22 Mg ha^{-1}, PN 11Mg ha^{-1} + N fertilizer, PN 22 Mg ha^{-1} + N fertilizer, PC 11 Mg ha^{-1} + N fertilizer, and PC 22 Mg ha^{-1} + N fertilizer. Soil moisture at 0-15 and 0-30 cm was measured periodically during the growing season by time domain reflectometry (TDR). Although the corn was irrigated, it experienced drought stress as evidenced by mid-day wilting due to drought conditions throughout the growing season (Georgia Automated Environmental Monitoring Network, 2006). Yield and total aboveground biomass were measured at harvest.

RESULTS

Feedstock and pyrolysis temperature affects char characteristics such as CEC and available nutrients. Analysis of chars produced at different temperatures from different feedstocks indicated that available nutrients were significantly higher in chars produced at 420°C compared to those produced at 380°C (Table 1). Of the common feedstocks tested, PN char contained higher nutrients than PC, PB, or HW chars.

Char CEC also varied with feedstock and pyrolysis temperature (Table 1). Cation exchange capacity ranged from 44.0 cmol kg $^{-1}$ char for PN 402 to 14.1 cmol kg $^{-1}$ char for the HW pyrolyzed at 426° C. Cation exchange capacity was significantly lower for feedstocks pyrolyzed at 420° C. Peanut hull pellet chars had a significantly higher CEC than other feedstocks. Tifton loamy sand soils amended with PN char (426 °C) at 22 Mg ha^{-1} had a small increase in CEC of 15% compared to the un-amended soil.

Soil amended with PC char (426°C) at 22 Mg ha^{-1} had a 5% increase in CEC. This preliminary screening indicates char has potential to improve both CEC and serve as a nutrient source. Moisture release curve data from a Tifton loamy sand indicated no effect of the char addition on water holding capacity at 11 and 22 Mg ha^{-1} rates (Figure 1 and 2). However, PN char additions of 88 Mg ha $^{-1}$ increased water holding capacity in this soil (Figure 1).

In general, there were also no differences in the average soil water content of the field treatments during the growing season. The average soil water content of the plots amended at 22 Mg ha^{-1} was higher than the control, but these differences were only significant on one date.

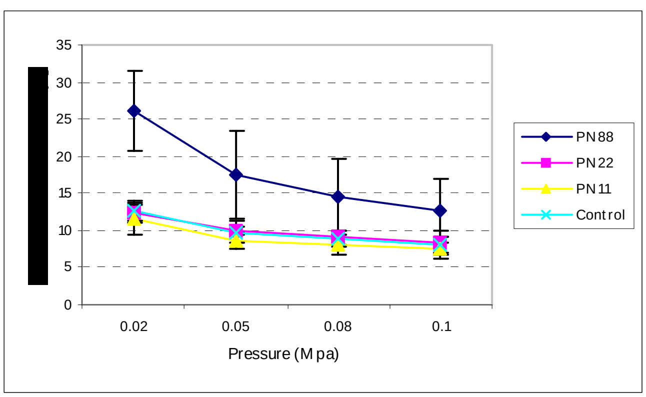

Figure 1. Moisture release curve for Tifton soil amended with peanut hull pellet (PN) char at 0 (control), 11, 22, and 88 Mg ha^{-1}

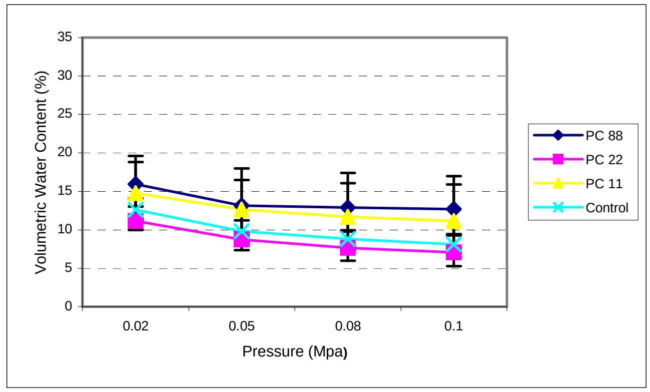

Figure 2. Moisture release curve for Tifton soil amended with pine chip pellet (PC) char at 0 (control), 11, 22, and 88 Mg ha^{-1}

Table 1. Available nutrients and CEC in chars from different feedstocks and produced under different conditions.

Char-Temp	C %	N %	P mg kg^{-1}	K mg kg^{-1}	Ca mg kg^{-1}	CEC cmol kg^{-1}
PN-371	68.1	2.03	585.8	6384	1181	36.6
PN-402	65.5	2.00	719.4	7714	1437	44.0
PN-426	64.2	1.95	769.3	8142	1562	25.2
SD-378	69.4	0.15	107.4	758	676	30.0
SD-399	70.9	0.15	80.6	665	541	30.5
SD-418	71.7	0.16	94.1	1121	567	14.4
PC-379	74.2	0.13	86.6	437	361	19.5
PC-401	76.0	0.14	88.8	659	379	27.0
PC-426	75.2	0.17	121.8	1287	529	18.6
PB-382	67.3	0.31	63.3	387	559	22.4
PB-399	67.0	0.29	69.0	530	913	19.0
PB-426	69.1	0.33	102.1	843	1048	17.1
HW-382	69.5	0.28	71.5	389	394	22.6
HW-400	70.3	0.30	87.0	688	529	23.0
HW-426	73.5	0.36	122.5	1131	576	14.1

DISCUSSION

Data from various studies indicate that feedstock, pyrolysis temperature and possibly other pyrolysis conditions effect char characteristics that influence how it functions in the soil. This is consistent with the literature on activated carbon. The CEC of the char varied with feedstock and pyrolysis temperature with temperature at or below 400 °C having the highest CEC. Although the CEC of the chars are not high compared to humus (200 cmol kg^{-1}, Brady and Weil, 1999), these are higher than the CEC typically found in Tifton soils (about 5 cmol kg $^{-1}$, Perkins, 1987). The addition of low rates of char increased CEC indicating the capacity of these low CEC soils can be increased with char addition. This is consistent with reports of CEC increases with char additions from Glaser et al. (2002).

Major et al. (2006) report the surface soils of Oxisols amended with char at 20 Mg ha^{-1} contained more water by volume and the water was held more tightly than un-amended soils. However, low rates of char addition do not appear to increase the water holding capacity of the loamy sand Tifton soil. Our data on moisture release curves indicate much higher single application rates may be necessary to significantly alter water relations in these soils. Tryon (1948) reported increases in available moisture with the addition of charcoal to sands at 15, 30 and 45% by volume.

It is known that the feedstock used for char production and the conditions under which it is produced affects its physical and chemical properties; however, this information is often not given in papers discussing charcoal effects on soils. Further work is needed to determine the potential for pyrolysis char to affect nutrient cycling and its potential effect on water quality in southeastern soils. Ongoing studies are evaluating the variability of char produced with different feedstocks, and under different temperature and carrier gas conditions, as well as the effect of these chars on soil water relations, nutrient cycling, plant growth, and yields.

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