Short-term impacts of biochar made from different feedstocks on soil quality and water holding capacity of arid soils

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BACKGROUND

Generally, arid soils have poor quality due to very low levels of soil organic matter [1]. Organic matter is very central to the quality of any soil [2]. The organic matter levels of arid soils, particularly in New Mexico where this study was conducted, are often less than 1% [3]; to improve the soil organic matter, considerable efforts are needed to add organic materials to the soil. Soil additions of biochar offer the possibility for improving soil quality and water holding capacity of desert soils that are used for agricultural production. Biochar is a predominantly recalcitrant organic carbon (C) material, created when biomass is heated to temperatures between 300°C and 1000°C under low oxygen concentrations (i.e., pyrolysis) [4]. Biochar has been reported to have positive effects on soils and crops. Improved soil indicators due to biochar amendment include soil nutrient supply, soil moisture retention, cation exchange capacity, soil microbial diversity and soil structure [5]. Most studies on biochar have been in humid climates; relatively few studies have been conducted in arid climate. This study addresses the gap in the knowledge of how biochar can impact arid agricultural soils.

OBJECTIVES

Assess the impacts of biochar amendments on soil moisture retention and multiple soil quality indicators in two different soil textures (sandy loam and clay loam).

MATERIALS AND METHODS

- Biochars made from 4 feedstocks were tested: pecan shells (PS), pecan orchard prunings (PP), cotton gin trash (CGT) and yard waste (YW)
- Agricultural field soils, a sandy loam and a clay loam, were amended with biochars from different feedstocks at a rate of 45 Mg/ha in a soil core. The treatments were compared to non-amended controls.
- Amended soil were incubated for three weeks in a growth chamber set at 28°C/20°C (day/night) with soil moisture maintained at about 85% of the soil's field capacity
- Water holding capacities of the amended soils were measured using a combination of a Hyprop tensiometer and a Dewpoint potentiometer
- Soils were also tested for multiple soil quality indicators including soil organic matter (SOM) content, pH, electrical conductivity (EC), and available nutrients
- Nutrient analysis was conducted using standard NMSU soil analysis laboratory protocols

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RESULTS

Table 1. Soil quality of biochar-amended soils including pH, electrical conductivity (EC), sodium adsorption ratio (SAR), soil organic matter (SOM), nitrate nitrogen (NO_3-N), phosphorus (Olsen P), potassium (K) and micronutrients (Cu, Mn, Fe, Zn).

Soil	Biochar Treatment	pH	EC	SAR	SOM	NO_3-N	Olsen P	K	Cu	Mn	Fe	Zn
			($dS \cdot m^{-1}$)		($g \cdot kg^{-1}$)	←			($mg \cdot kg^{-1}$)			→
Sandy loam	Control	7.45	1.45 a	4.5 b	0.55 a	3.7	6.0 a	26 a	1.2	3.4 a	2.7 b	0.86 a
	PS	7.48	1.28 a	3.7 ab	0.49 a	2.5	6.1 a	34 a	1.1	6.1 b	2.8 b	0.88 a
	PP	7.40	2.00 a	3.9 ab	0.51 a	2.7	7.1 a	43 a	1.0	8.4 c	2.6 ab	1.12 b
	CGT	7.41	7.12 b	2.9 a	1.16 b	0.8	25 b	361 b	0.9	11.6 d	2.4 a	1.08 b
	YW	7.43	1.25 a	3.8 ab	0.65 a	1.9	6.4 a	35 a	1.2	8.7 c	2.5 ab	0.90 a
		ns				ns			ns			
Clay loam	Control	6.90 a	6.86 a	4.3 a	1.19 a	136 a	12 a	60 a	2.3	4.5 a	3.4 b	0.88
	PS	7.03 ab	7.47 a	4.9 ab	1.20 a	138 a	13 a	70 a	1.6	7.0 b	3.6 b	0.95
	PP	6.88 a	15.5 c	6.9 c	1.24 a	759 c	12 a	113 c	2.1	7.5 bc	2.5 a	1.19
	CGT	7.08 b	9.12 ab	5.3 b	1.89 b	1 a	28 b	252 d	1.7	8.2 cd	2.8 a	1.07
	YW	6.90 a	12.0 b	5.7 b	1.33 a	466 b	13 a	92 b	1.5	8.8 d	2.7 a	1.94
									ns			ns

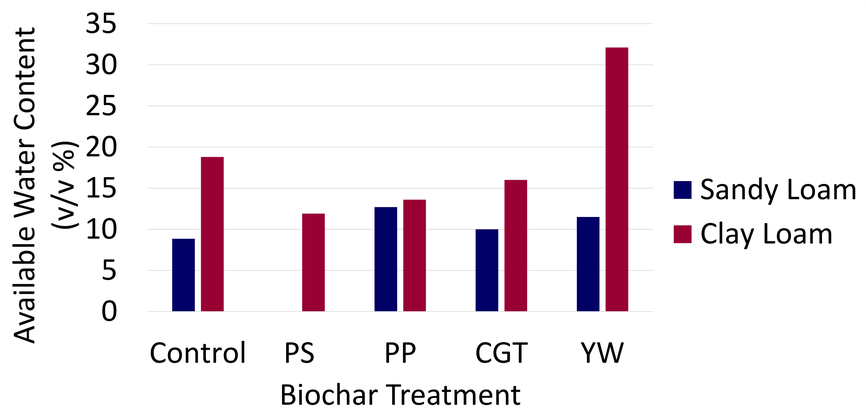

Figure 1. Preliminary available water content results for biochar-amended soils. Available water contents estimated by fitting a bimodal Van Genuchten-Mualem model [6] to soil tensiometer and dewpoint potentiometer data, assuming field capacity at -33 kPa and permanent wilting point at -1.5 Mpa. Additional soil moisture measurements are ongoing.

- pH did not show a significant difference with biochar treatment in sandy soil but CGT led to slightly higher pH in clay soil (Table 1).
- While NO_3-N was not affected by the treatments in sandy soil, PP and YW led to higher NO_3-N in clay soil (Table 1).
- CGT led to higher SOM in both soils presumably due to soil particles present in the CGT feedstock (Table 1).
- Amending sandy soil with CGT biochar led to a P increase of about 4.2 times and a K increase of about 13.9 times compared with the control treatment, but salinity resulting from CGT amendment was also 5 times the control treatment (Table 1).
- In clay soil CGT treatment also led to higher P and K additions compared to the control and other biochar treatments, but the increase in soil salinity due to CGT amendment was only 1.3 times the control treatment (Table 1)
- Biochar treatment effects on micronutrient levels in the soil were very varied with no significant differences for Cu in both soils and for Zn in clay soil. Manganese seems to the only micronutrient that experienced considerable increase due to biochar treatments (Table 1).

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CONCLUSIONS

Amending clay loam and sandy loam agricultural soils with biochars from pecan shells, pecan orchard prunings, and yard waste had few significant impacts, positive or negative, on the soil quality indicators measured in this study after a short soil incubation. Biochar effects were different for the two different soil textures. Cotton gin trash biochar showed the greatest potential to increase soil organic matter and plant nutrients, however, the increases in salinity for both soils is a serious concern. Biochar amendments preliminarily appear to increase available water content in sandy loam soils; effects are unclear for clay loam soils.

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