Land-application of Gasification Biochar

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Background and Justification

- Gasification, or controlled partial combustion, of biomass is currently being evaluated as a method of bioengergy production. Gasification produces syngas (a biofuel) and a biochar co-product.
- The biochar co-product is composed of highly carbonized biomass residuals and contains minerals found in the original biomass, which could benefit plant growth if as a soil amendment.
- Returning biochar to soil may be an effective method of nutrient recycling in bioenrgy production systems. Therefore, biochar may increase productivity of marginal lands and improve the sustainability of bioenergy systems. Furthermore, the nutrient and soil amendment value of biochar could be an economic benefit to bioenergy producers.
- However, biochar impacts on plant growth and soil nutrient availability are not fully understood.

Objectives

Determine the effects of biochar application on forage sorghum production, N response, and soil fertility properties.

Methods

Biochar Description

Biochar used for this study was produced from gasification of wheat middlings in a demonstration scale horizontal gasifier by ICM Inc., Colwich, KS.

Table 1. Physical and chemical analysis of biochar co-produced from gasification of wheat middlings.

Property	result	units
Volatile Matter	178 ±14	g kg^{-1}
Ash	231 ±9	g kg^{-1}
Specific Surface Area	11 ±9	m^2 g^{-1}
Cation Exchange Capacity	28.4 ±5.4	cmol kg^{-1}
C	635 ±61	g kg^{-1}
H	10.4 ±1.2	g kg^{-1}
N	40.0 ±2.9	g kg^{-1}
S	2.5 ±0.2	g kg^{-1}
P	12.3 ±3.3	g kg^{-1}
Water Extractable P	41 ±9	%
K	11.1 ±2.5	g kg^{-1}
Ca	1.9 ±0.5	g kg^{-1}
Mg	4.3 ±1.5	g kg^{-1}
Fe	240 ±63	mg kg^{-1}
Zn	119 ±24	mg kg^{-1}
Cu	24 ±16	mg kg^{-1}
Mn	144 ±41	mg kg^{-1}

Field Experiment

A split-plot field experiment was carried out in 2011 and 2012 to determine biochar effects on soil nutrient availability (N, P, and K), soil pH, and biomass sorghum growth.

- Locations (see Table 2 for initial soil properties)
  - Buttler, MO - silty clay loam
  - St. John, KS - Carwile f. sandy loam (fine, mixed, superactive, thermic Typic Argiaquolls)
- Whole-plot treatments (12.2 x 9.1 m)
  - control (no biochar, no fertilizer, no lime)
  - fertilizer + lime (1300 kg ECC ha^{-1}, 45 kg P ha^{-1} yr^{-1}, 180 kg K ha^{-1} yr^{-1})
  - Biochar (37 Mg ha^{-1} applied in April 2011)
- Sub-plot treatments (3 x 9.1 m)
  - N fertilizer rates of 0, 60, 120, 180 kg N ha^{-1}
- Crop - Hybrid forage sorghum 1990 (Sorghum Partners, Inc., New Deal, TX)
- There was severe drought at the St. John in 2011.

Table 2. Initial soil analysis at the field locations.

Location	CEC	pH	Total C	Total N	Mehlich 3 P	K	Ca	Mg
	cmol kg^{-1}		—— g kg^{-1} ——		——— mg kg^{-1} ———			
Butler, MO	22.3	6.3	21.2	1.8	13	133	2789	367
St. John, KS	5.2	5.2	3.6	0.4	34	102	326	48

Biochar Impacts on P, K, and pH

Table 3. Biochar (whole-plot treatments) significantly affected several soil properties, including P, K, and soil pH, as seen in the following ANOVA table.

Effect	CEC	pH	TN	TC	M3 P	K	Ca	Mg
Biochar	-	**	***	***	***	***	**	-
N rate	-	-	-	-	-	-	-	-
Location	***	***	***	***	***	-	***	**
Biochar*N rate	-	-	-	-	-	-	-	-
Biochar*Location	*	***	***	***	-	-	***	*
N rate*Location	-	-	-	-	-	-	-	-
Biochar*N rate*Loc	-	-	-	-	-	-	-	-

Figure 1. Biochar P was released slowly over time and increased soil test P by 0.35 mg P kg^{-1} soil per unit (kg ha^{-1}) of P applied by the end of the 2011 growing season, compared to 0.57 at the KS site and 0.07 at the MO site with fertilizer.

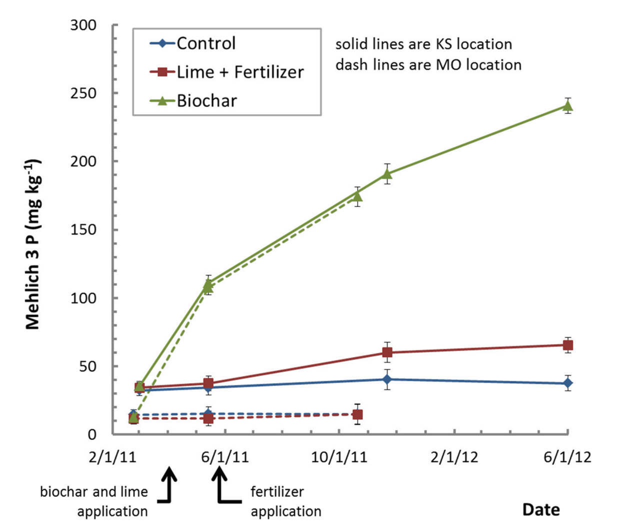


Figure 2. Biochar K release was similar to P release and increased soil test K and was as effective or more effective at increasing soil test K relative to fertilizer (per unit of K applied).

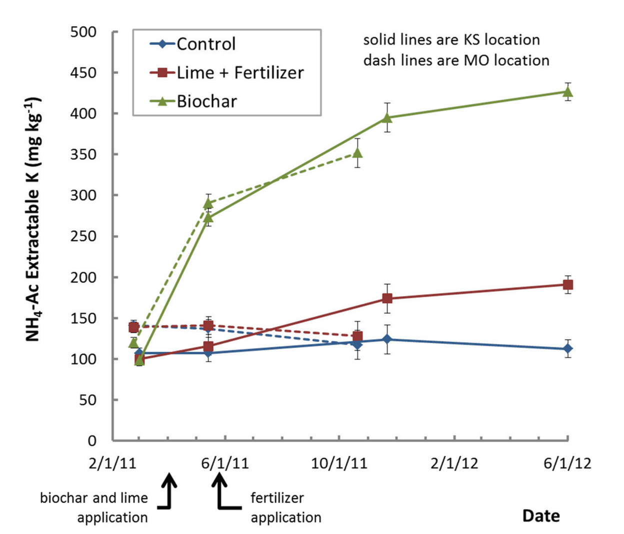


Figure 3. Biochar was very effective an increasing pH at the KS site (sandy soil). Biochar impact on pH was minimal at the MO site.

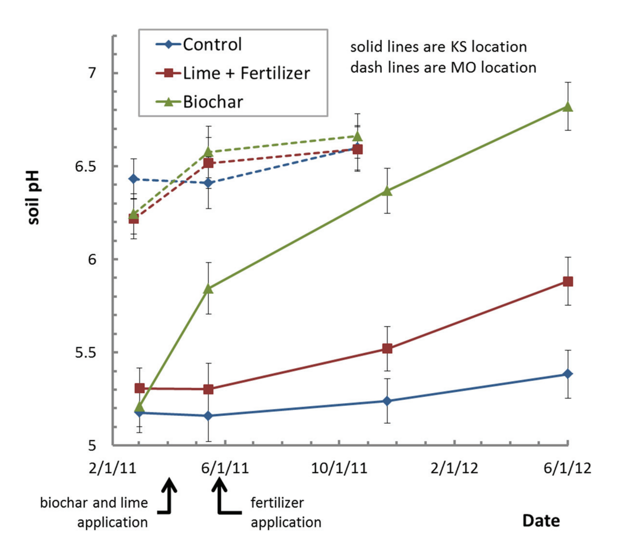


Table 4. Biochar effects on cation exchange capacity (CEC), total C (TC), total N (TN), Ca and Mg.

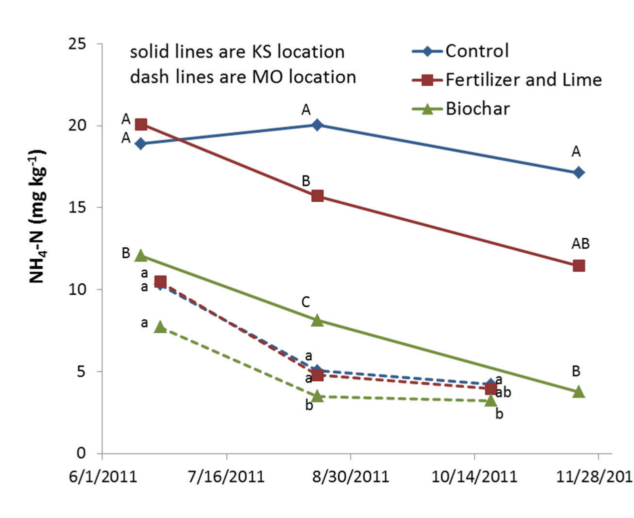
Date (treatment)	Kansas CEC	Kansas TC	Kansas TN	Kansas Ca	Kansas Mg	Missouri CEC	Missouri TC	Missouri TN	Missouri Ca	Missouri Mg
	cmol kg^{-1}	g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	cmol kg^{-1}	g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}
Control	3.0	3.1	0.4	267	64	21.8	22.7	2.1	2928	411
Lime+Fertilizer	3.8	3.6	0.4	356	66	20.9	21.8	2.0	2968	367
Biochar	3.7	9.0	0.8	287	106	21.2	35.1	2.8	2716	469

Nitrate and Ammonium over time

Biochar application decreased the NH_4-N concentrations in the 0-15 cm soil depth for the duration of the experiment in 2011. Biochar effect on soil NO_3-N concentrations was similar, but less significant (data not shown).

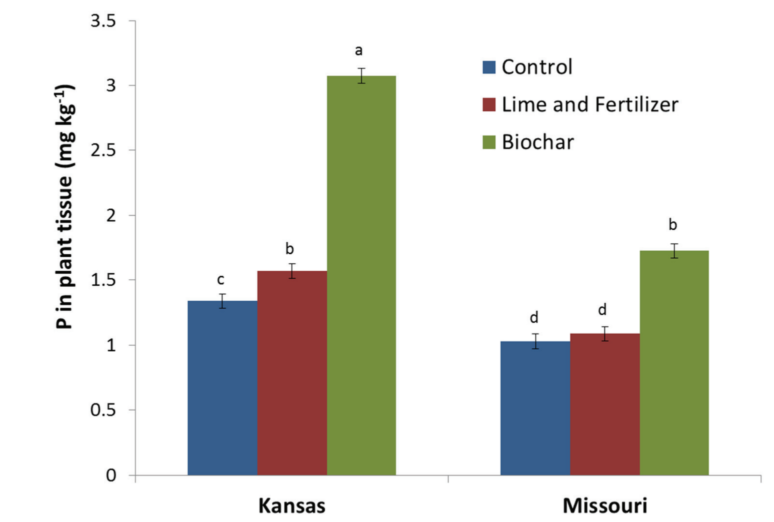
Table 5. ANOVA results for NH_4-N and NO_3-N in the 0-15 cm soil depth.

Effect	NH_4-N June	NH_4-N Aug.	NH_4-N Nov.	NO_3-N June	NO_3-N Aug.	NO_3-N Nov.
Biochar	**	***	*	**	-	-
N rate	***	***	***	***	***	***
Location	***	***	*	-	**	*
Biochar*N rate	-	***	***	-	-	*
Biochar*Location	-	***	***	***	-	-
N rate*Location	***	***	***	-	***	**
Biochar*N rate*Loc	-	***	**	*	-	-

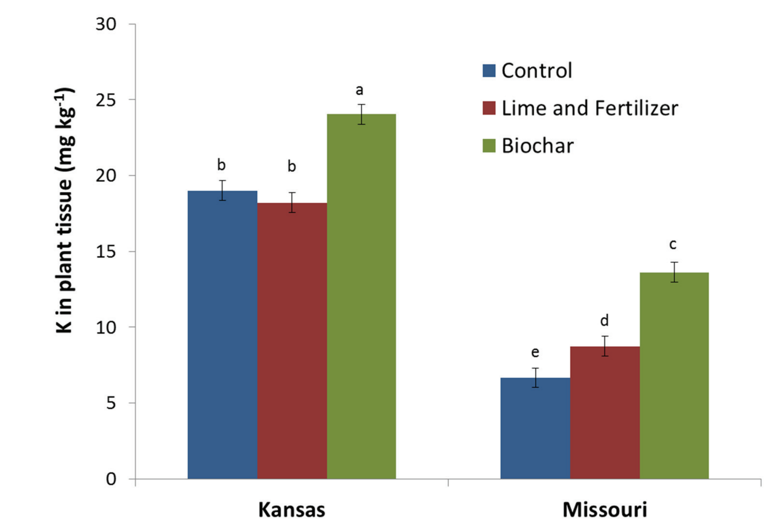


Yield and Plant response

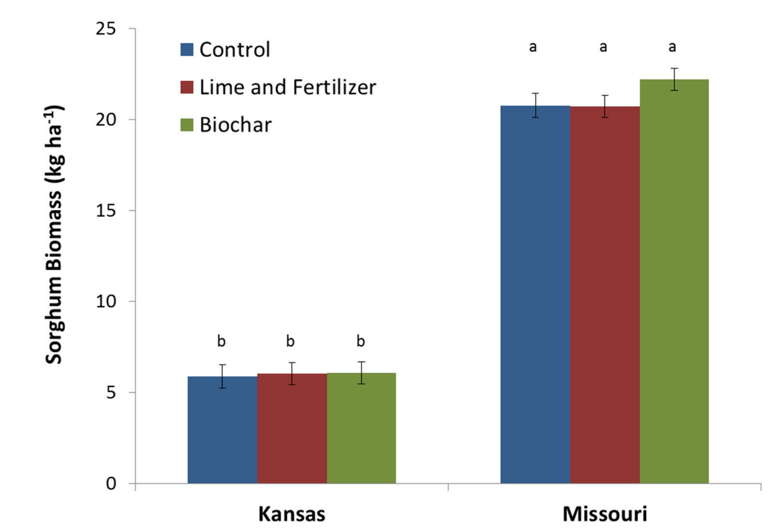
Biochar increased the P concentration in the plant tissue at both locations



Biochar increased the K concentration in the plant tissue at both locations

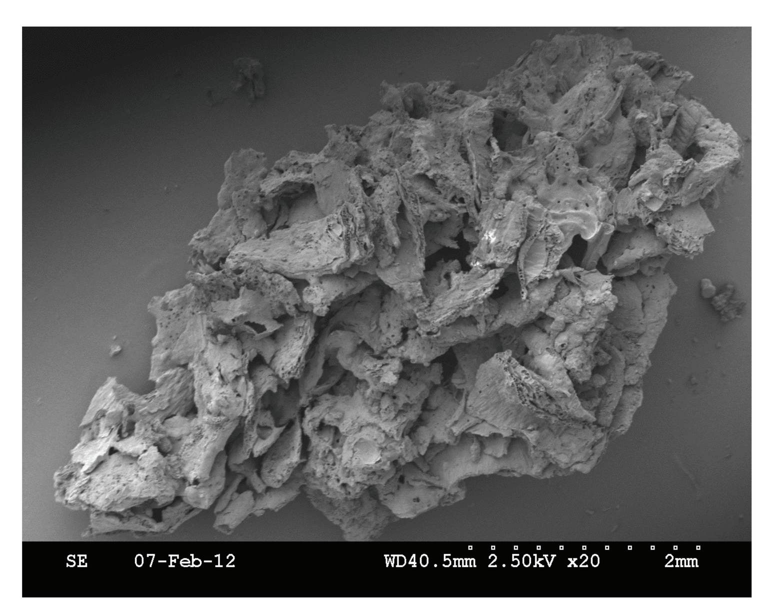


Biochar did not impact the sorghum yield at either location. Sever drought impacted yield in Kansas, which could have interfered with plant growth response to biochar.



Conclusions

- Biochar from gasification is an effective method of supplying P and K to the soil and plants.
- Biochar increased soil pH and can be an effective liming material
- Biochar tended to reduce NH_4-N concentrations in the soil.
- There was no effect of biochar on plant yield, but the yield results may be confounded due to severe drought at one location.
- Total C and total N both increased substantially with biochar applications.
- The experiment will be continued to determine long-term effects of biochar on yield, nutrient availability, and soil properties.



Acknowledgements

We appreciate the collaboration and assistance of Glen Newdigger and acknowledge the cooperation of Stafford County, KS for use of their land to conduct this study.