Microbial Enzyme response to Biochar as a Soil Amendment for Corn (*Zea mays* L.) and Wheat (*Triticum aestivum* L.)

University of Minnesota
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INTRODUCTION

Biochar, produced through pyrolysis and gasification, can produce oil and gas by-products that can be used as fuel, providing clean, renewable energy. When used as a soil amendment, these by-products have been reported to improve crop yield, increase availability of plant nutrients, increase soil moisture retention, reduce greenhouse gas emission, and sequester carbon. A greenhouse experiment was conducted at the University of Minnesota, Southwest Research and Outreach Center near Lamberton to evaluate soil chemical and biological properties and crop responses to by-product amendments. This poster reports the results related to the biological responses to different biochar material and application rates.

OBJECTIVES

The objective of this experiment was to measure chemical and biological activities in soil amended with pyrolysis, gasification and combustion biochar/ash products:

Ash- Turkey Manure Combustion Ash
C/S- Wood/Corn Cob/Stover Gasification Biochar
Switch- Switchgrass Pyrolysis Biochar

MATERIALS AND METHOD

By-product amendments:
Ash – combustion by-product
C/S - gasification by-product
Switch - pyrolysis by-product

Rates of application:
11.2 Mg ha^{-1}
22.4 Mg ha^{-1}
44.8 Mg ha^{-1}
0 Mg Biochar ha^{-1} (control treatment)

The soil series tested:
(Table 2)
Barnes loam
Canisteo clay loam
Hubbard loamy sand

Crop treatments:
Fallow without plants
Corn (*Zea mays* L.) thinned to 2 plants/pot
Wheat (*Triticum aestivum* L.) thinned to 6 plants/pot

Experiment set up:

Plants were grown in 2.1 L pots for 56 days along with a fallow treatment. The experiment was set up in a completely randomized block design replicated four times. The environment was maintained at 21 to 27°C during a 14 hr photoperiod, and 16 to 21°C at night. Plants were watered to maintain soil at or near field capacity.

Data collection:

Soil samples were collected from all pots at the beginning (day 0) and also on days 7, 28, and 56. Samples were analyzed for total C, total N, total S, ammonium, nitrate, and pH. Biological analysis of these soils included analysis of enzyme activity including the enzyme: sulfatase, glycosidase, and acid phosphomonoesterase.

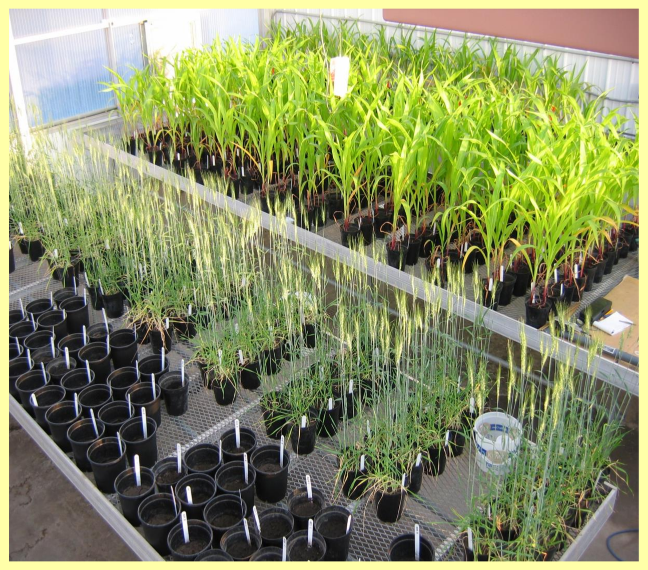

Table 1. – Chemical properties of turkey manure ash (TMA), switchgrass ash (SWA), and wood/corn cob ash (WCCA).			
Chemical property	TMA	SWA	WCCA
Calcium Carbonate Equivalent (CCE) %	29.5	8.5	35.6
Effective Calcium Carbonate Equivalent (ECCE) %	22.7	6.6	35.4
pH (1:1 water)	12.0	9.4	11.4
Total Phosphate (P_2O_5) %	10.6	1.0	0.32
Available† P (P_2O_5) %	3.6	ND	ND
Available ‡ K (K_2O) %	-	-	-
Chloride (g/kg)	25.1		3.5
Acid-digestible elements			
		g kg^{-1}	
Aluminum	4904	-	1801
Calcium	162	11.6	130
Iron	4.3	0.40	3.5
Magnesium	17.3	12.0	6.5
Manganese	1.1	0.12	0.70
Phosphorus	-	-	-
Potassium	58.9	2.6	16.7
Sodium	13.0	0.6	2.2
Sulfur	15.2	1.3	ND
Zinc	0.87	0.10	0.14
		mg kg^{-1}	
Arsenic	15.1	-	8.1
Boron	98	ND	34
Cadmium	3.5	-	1.4
Cobalt	3.9	-	3.2
Copper	874	ND	46
Chromium	14.1	-	7.2
Molybdenum	8.8	-	9.2
Nickel	19.9	-	10.5
Lead	52.3	-	61.5
Selenium	10.8	-	9.5

Table 2. – Initial Characteristics of three soils Barnes, Canisteo and Hubbard, prior to addition of amendment.

Parameter	Barnes	Canisteo	Hubbard
Total C, g kg^{-1}	28.9	27.3	8.6
Total N, g kg^{-1}	22.9	24.7	8.5
NH^{+4}-N, mg kg^{-1}	16.9	20.0	17.4
NO^{-3}-N, mg kg^{-1}	10.4	4.8	3.0
Olsen P, mg kg^{-1}	23	12	5
Exchangeable K, mg kg^{-1}	197	155	90
pH in Water	8.1	6.4	5.7
pH in $CaCl^{-2}$	7.5	5.7	4.9

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RESULTS

Sulfatase Activity

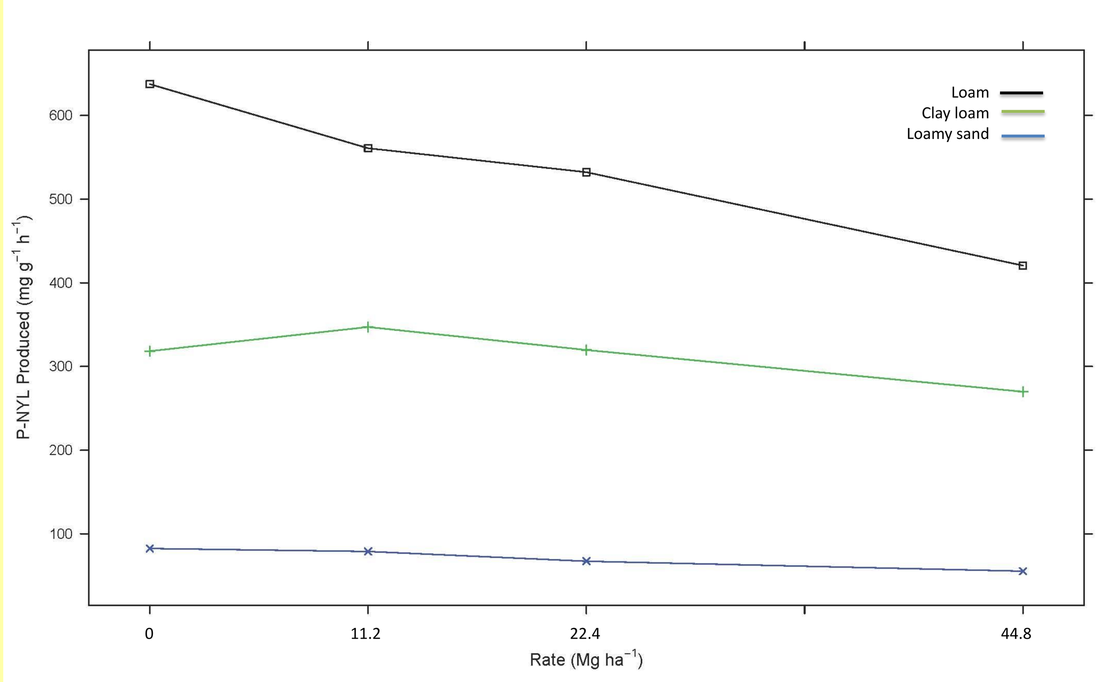

Figure 1a. P-nitrophenol produced in response to sulfatase activity at various biochar rates among the three soil types.

- Sulfatase activity was consistently highest in the Barnes loam and lowest in the Canisteo loamy sand regardless of source, rate or time.
- As application rates increased, sulfatase activity in all soil types decreased (Figure 1a).
- Over time, sulfatase activity in the three soils demonstrated an initial sharp increase with activity leveling off to a constant rate differing only in magnitude among the three soils (Figure 1b).

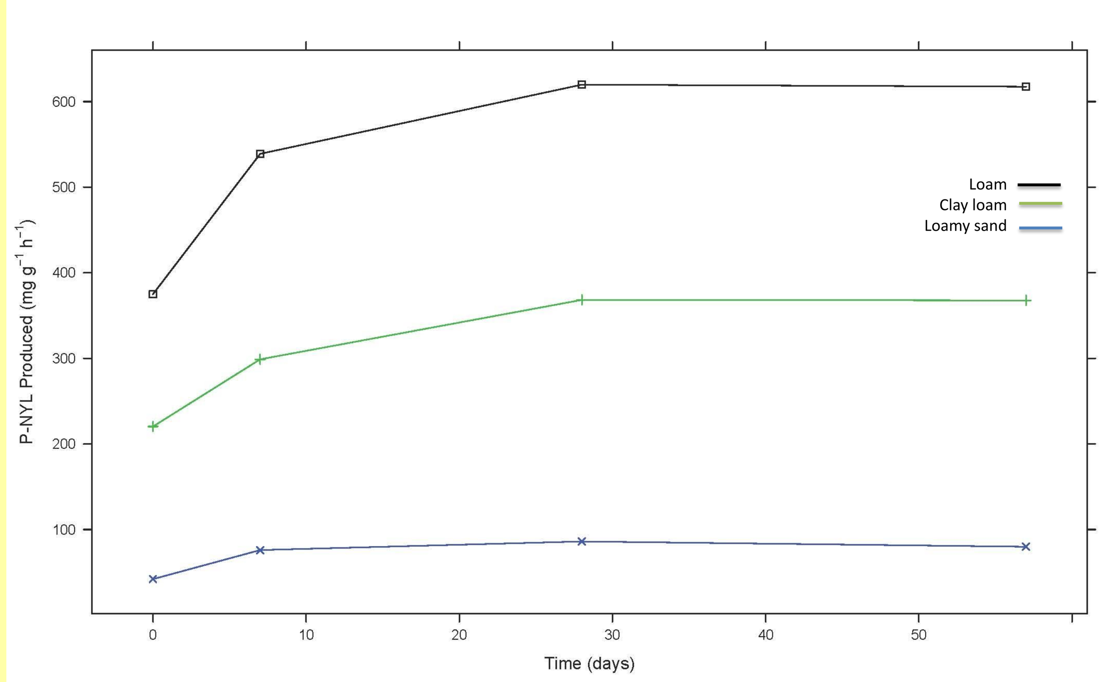

Figure 1b. P-nitrophenol produced in response to sulfatase activity among the three soil types as a function of time.

Phosphatase Activity

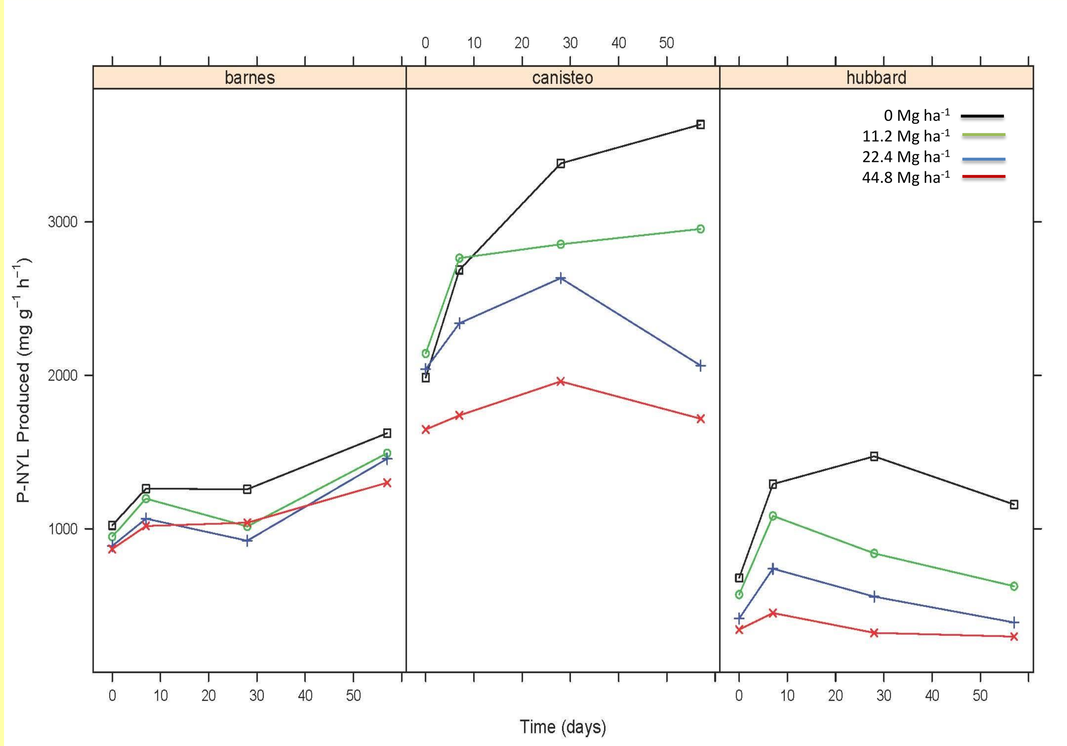

Figure 2a. P-nitrophenol produced in response to phosphatase activity at various biochar rates over time among the three soil types.

- Phosphatase activity was consistently highest in the Canisteo clay loam and lowest in the Hubbard loamy sand.
- Over time, Phosphatase activity behaved differently among the three soils. Barnes loam demonstrated little difference among application rate over time, however the Canisteo clay loam and Hubbard loamy sand showed Phosphatase activity decreasing as rate increased (Figure 2a).
- The two highest application rates in the Canisteo clay loam show a significant decline in activity with time (Figure 2a, middle panel).
- The addition of any biochar resulted in a decrease of phosphatase activity; the higher rate of biochar resulted in a greater reduction of enzyme activity (Figure 2b).

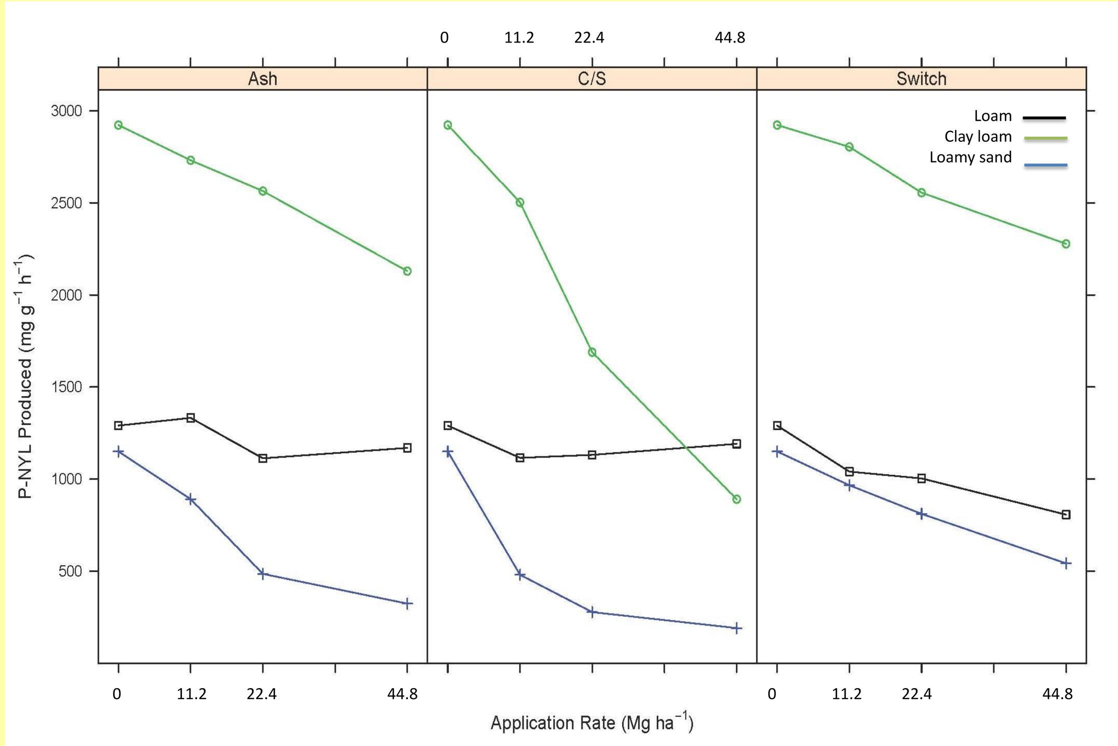

Figure 2b. P-nitrophenol produced in response to phosphatase activity in the three soil types amended with different biochar material at various application rates.

Glucosidase Activity

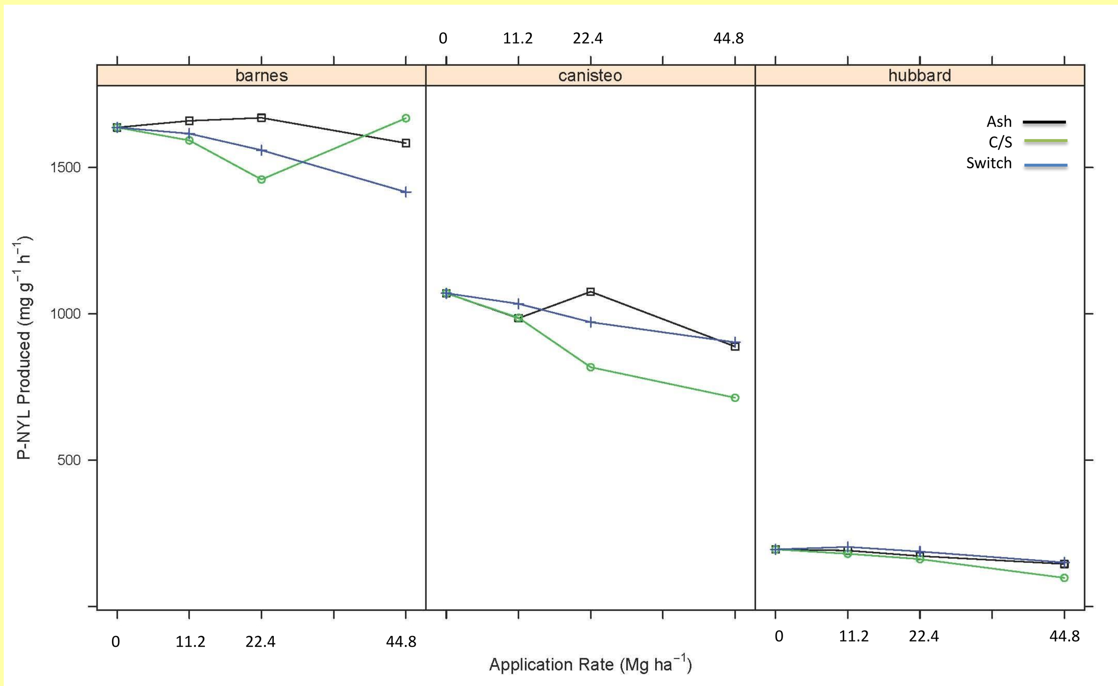

Figure 3a. P-nitrophenol produced in response to glucosidase activity in three soil types amended with different biochar material at various application rates.

- Glucosidase activity was consistently highest in the Barnes loam, and lowest in the Hubbard loamy sand.
- Glucosidase activity tended to increase in response to the Ash amendment with rates up to 22.4 Mg ha^{-1} and the higher rate caused a decrease in glucosidase activity (Figure 3a).
- All three sources of biochar responded similarly in the Hubbard loamy sand; glucosidase activity was fairly steady for all rates (Figure 3a, right panel).
- Over time, glucosidase activity tended to be highest around day 30 and decreased after that (figure 3b).

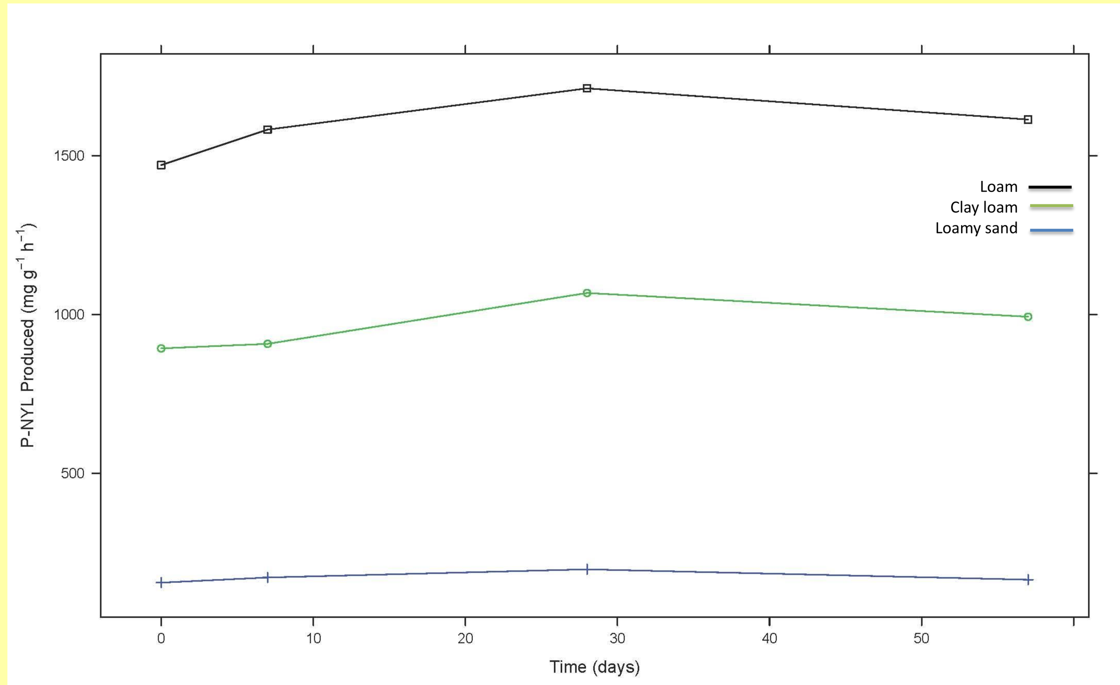

Figure 3b. P-nitrophenol produced in response to glucosidase activity in the three soil types over time.

CONCLUSIONS

•In all pots, enzyme activity increases immediately at the start of the experiment, then tended to quickly level off or only slightly increased in activity as the experiment progressed. However there were situations when activity declined as the experiment progressed, which seemed to be related more with addition of Switchgrass biochar in the Canisteo and Hubbard soils.
•Phosphatase was most sensitive to treatment and rate of the soil biochar amendments regardless of soil type. Of the three enzymes studied, Glucosidase activity was the least variable as a function of rate, time, and biochar source.
•Soils that did not have any biochar added had higher enzyme activity than those pots that were amended with a biochar treatment across all soils. In most cases as the application rate increased the level of enzyme activity decreased.
•In the Barnes loam, it was most evident in the sulfatase activity in the C/S and Switchgrass treaments.
•In the Canisteo clay loam, higher rates of C/S biochar reduced rates of both Glucosidase and Phosphatase.
•In the Hubbard loamy sand, higher rates of all three biochar sources reduced phosphatase activity, and addition of the C/S biochar reduced Glucosidase activity.
•In pots that received the highest rate, the effects often led to reduction in total plant biomass.
•The only time we saw an increase in enzyme activity due to biochar addition was a slight increase in glucosidase activity in the lowest rates of the Ash biochar in Barnes loam and Canisteo clay loam.
•Further analysis of CO2 flux data may add additional insight to how the addition of different rates of biochar effect the microbial communities.