Effect of Hemp Residue Management on Biological Soil Health Indicators

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ABSTRACT

Hemp (*Cannabis sativa* L.) has the potential to capture and convert high amounts of atmospheric carbon dioxide (CO_2) to biomass through bio-sequestration. A potential use of hemp biomass could be conversion to biochar for use as a soil health amendment. Biochar amended soil has been documented to not only increase carbon storage in soil but also mitigate greenhouse gas (GHG) emissions like CO_2 and nitrous oxide (N_2O). Biochar addition to soil has many benefits including stimulation of specific soil microorganisms, soil enzymatic activity, soil respiration which could lead to enhanced biological activity and nutrient cycling or retention. However, limited studies have reported the effect of hemp derived biochar on biological soil health indicators. The objective of this experiment is to conduct a laboratory incubation to investigate the effects of hemp biochar, hardwood biochar (pyrolysis temperature of 800℃) and hemp residue (representing a range of C:N ratio) on soil microbial population and enzyme activity. Soil samples (0-10 cm) was collected from two experimental locations in NC; namely NC A&T research farm, Greensboro and Center for Environmental Farming Systems (CEFS) small farm unit, Goldsboro representing different climatic conditions, soil characteristics, and soil management histories. A 72-d laboratory incubation study was conducted at different moisture conditions and soils were destructively sampled on day 30 and 72 of the incubation experiment. Soil samples were then analyzed for biological soil health indicators i.e., enzyme activity and phospholipid fatty acid analysis (PLFA). Our preliminary results suggest that hemp residue with the lowest C:N ratio ~40 significantly stimulated soil enzyme activity in the first 30 d of the incubation experiment as compared to other amendments.

INTRODUCTION

- The interest in hemp and its benefits has spurred since significant changes in the legalization of hemp in the USA. North Carolina is in its 4th year of the hemp pilot program and ranks 6th in the no. of cultivator licenses and amount of hemp acreage in the United States. Hemp is an unconventional crop with a broad spectrum of adaptation throughout North America including seeds, fiber and medicines. Hemp is also considered as an environmentally friendly and highly sustainable crop (Montford et al., 1999) due to its potential to improve soil health and improve environmental quality.
- Currently the agriculture sector is a net producer of greenhouse gas emissions both directly through conventional farming practices that deplete soil organic carbon stocks and N fertilizer additions that lead to emissions of nitrous oxide and carbon dioxide and indirectly through land use change (Lal, 2004; IPCC, 2018). Hemp's fast growth makes it one of the fastest sources of CO_2-to-biomass conversion. Hemp has been proven to be an ideal carbon sink as it can capture more CO_2 per hectare than other commercial crops. Hemp can sequester higher amounts of carbon by photosynthesis and then store it in the plant's body and roots through bio-sequestration. One other potential use of hemp biomass would be production of biochar for soil application.
- Biochar is a carbon-rich product generated from a controlled process called pyrolysis, a thermal decomposition of biomass (wood, manure, crop residues etc.) in an oxygen-limited environment. Pyrolysis converts 10–50% of the original biomass carbon into biochar carbon, which is more stable, persists in soils for hundreds to thousands of years and is steadily over a long time period. Several field and laboratory incubation studies have proved that biochar may improve soil microbial community stricture and reduce the greenhouse gas emissions from soil management practices (Lehmann et al., 2006; Bass et al., 2016; Fidel et al., 2019).

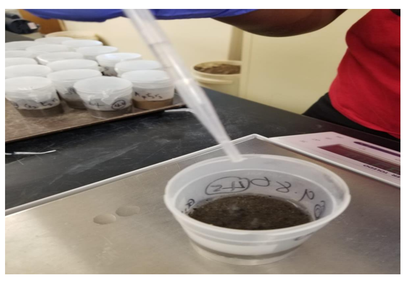

Fig 1 and 2: Hemp residues added to soil incubation experiment and maintained at fixed moisture content.

OBJECTIVE

- The objective of this study is to evaluate the effect of hemp biochar, hemp residue and hardwood biochar on soil microbial population and enzyme activity

MATERIALS & METHODS

- **Soil sampling:** Composite soil samples (0-15 cm) were collected from 2 sites; the Center for Environmental Farming Systems (CEFS) in Goldsboro NC A&T research farm in Greensboro. These soils represent coastal soil and piedmont soil respectively as well as different climatic conditions, soil characteristics, and soil management histories
- **A 72 -d lab incubation experiment was designed (Fig 2)**
  - **Amendments**: Hemp residue (**HR;** C:N= 38.8**),** Hemp biochar (**HB;** C:N=65.4), Hardwood biochar (**HA;** C:N=172.5) @ 0.5% (dry wt. added to dry soil)
  - **Soil microcosms were maintained at** 60% WFPS for 72 days or followed a 7d dry-wet cycle
- **Biological soil health indicators analysis:**
  - Soil enzymatic analysis was conducted by using the Synergy HTX multimode microplate reader spectrophotometer (Biotek Instruments Inc., Winooski, VT)
  - Soil lipids were extracted with a one phase cholorform:methanol:phosphate (1:2:0.8) buffer, with phospholipid fatty acids (PLFA) eluted from silicic acid columns in methanol, following removal of non-polar lipids by washing with chloroform and acetone. An aliquot of the total PLFA extract was used to estimate viable biomass by colorimetric assay for phospholipid phosphate (Findlay et al., 1989).

RESULTS & DISCUSSION

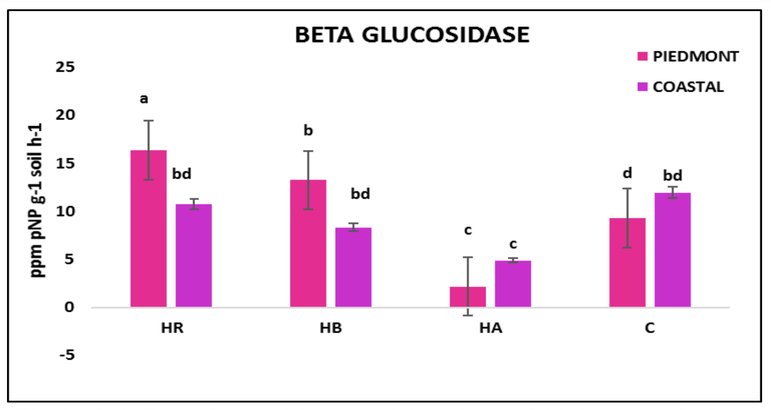

Fig 3: Soil Beta Glucosidase activity showed higher trends in all Piedmont soil as compared to coastal soil across the treatments except for HA and control soils, with a high rate of increase in HR and HB amended soils at d30. Error bars represent standard

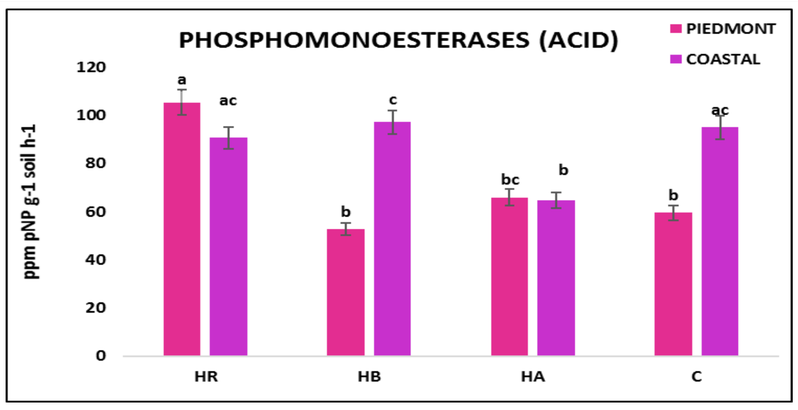

Fig 4: The activity of Phosphomonoesterases was higher in soils amended with HB for coastal soil whereas Piedmont soil amended with HR has highest activity at d30. Error bars represent standard

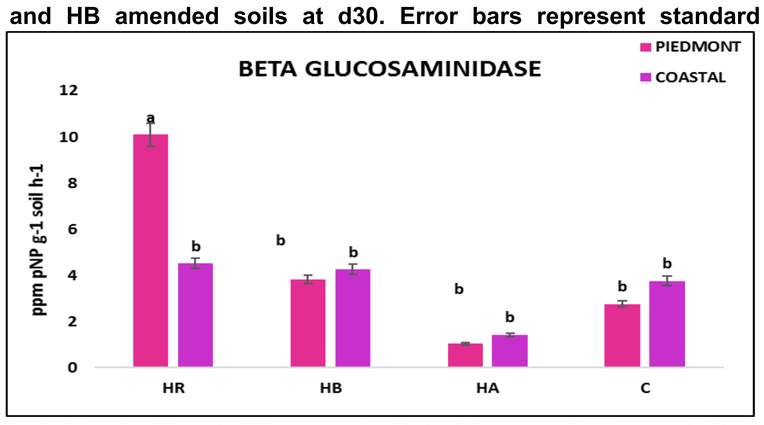

Fig 5: No significant difference in Beta Glucosaminidase activity in both soils across all treatment except for HR treatment in piedmont soil which was significantly higher at d30. Error bars represent standard error.

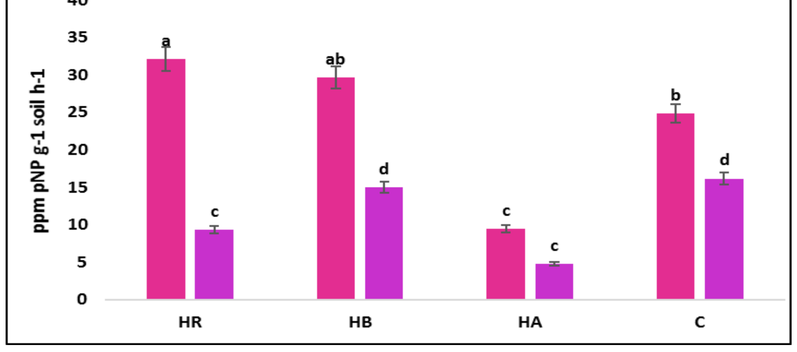

Fig 6: Phosphodiesterase activity was significantly higher in soils collected from Piedmont as compared to Coastal soils across all amendments at d30. Error bars represent standard error.

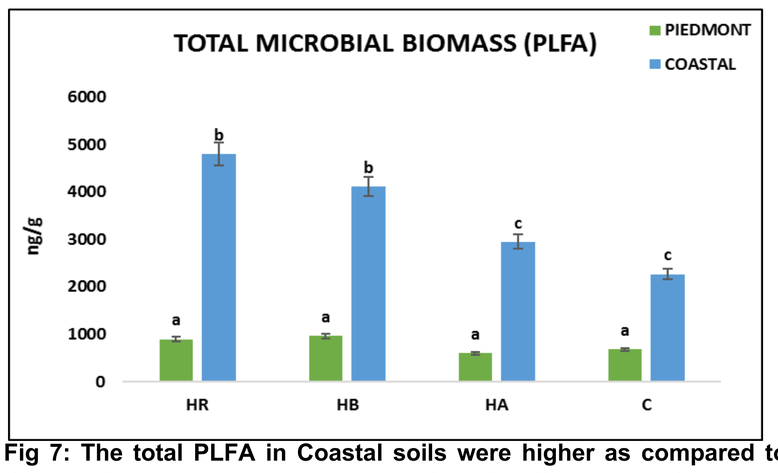

Fig 7: The total PLFA in Coastal soils were higher as compared to Piedmont which showed no significant difference between all treatments . Total microbial biomass in coastal soil was significantly higher in soils amended with low C:N ratio biomass at d30. Error bars represent standard error.

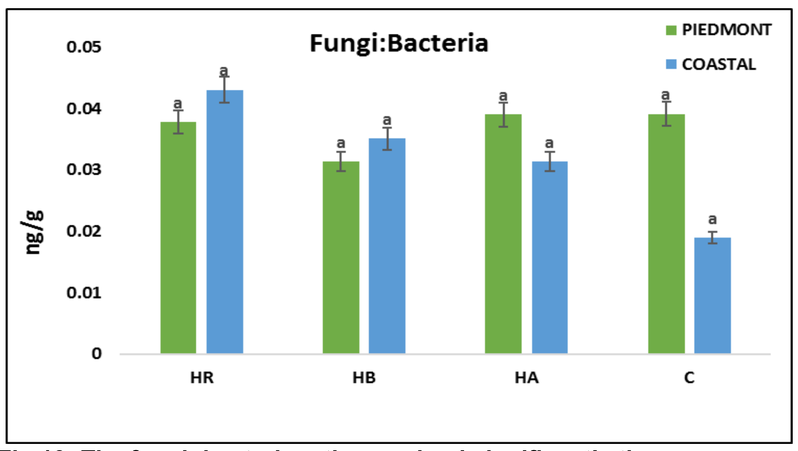

Fig 10: The fungi: bacteria ratio remained significantly the same across all treatments in both Piedmont and Coastal soil at d30. Error bars represent standard error.

Table 1. Correlation matrix showing the interactions between the soil microbes and enzyme activity at d30

	B.Glucosidase	*P.Diesterase*	*B.Glucosaminidase*	*P. Monoesterases*	*Arylsulfate*	*Total PLFA*	*Bact. Biomass*	*Fung. Biomass*	*Fung:Bact*	*Gram-:Gram+*	*Sat:Unsat*
Beta-Glucosidase	1										
Phosphodiesterase	0.72	1									
Beta-Glucosaminidase	0.74	0.47	1								
Phosphomonoesterases	NS	NS	0.61	1							
Arylsulfate	0.81	0.75	0.68	NS	1						
Total PLFA	NS	-0.53	NS	NS	NS	1					
Bact. Biomass	NS	-0.47	NS	NS	NS	0.97	1				
Fung. Biomass	NS	NS	NS	NS	NS	0.87	0.84	1			
Fung:Bact	NS	NS	NS	NS	NS	NS	NS	0.57	1		
Gram-:Gram+	NS	NS	NS	NS	NS	NS	NS	-0.56	-0.74	1	
Sat:Unsat	NS	NS	NS	NS	NS	-0.58	-0.63	-0.56	NS	NS	1

- Total PLFA positively correlates with bacteria biomass and fungi biomass
- Enzyme B. glucosidase positively correlates with phosphodiesterase, beta-glucosaminidase and arylsulfate

CONCLUSIONS

- Hemp biochar as an organic amendment has the potential to alter soil microbial, population and enzyme activity.
- Hemp residue with the lowest C:N ratio ~40 significantly stimulated soil enzyme activity in the first 30 d of the incubation experiment as compared to other amendments.

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