Biochar and Mill Ash Use as Soil Amendments to Grow Sugarcane on Sandy Soils in South Florida

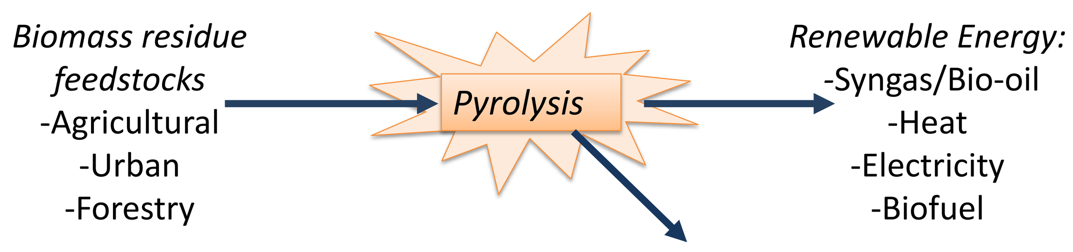
Odiney Alvarez, Timothy A. Lang, Jehangir H. Bhadha, Mabry McCray, Bin Gao, Barry Glaz, and Samira H. Daroub

Everglades Research and Education Center, Belle Glade, FL and Soil and Water Science Department, Gainesville, FL

INTRODUCTION

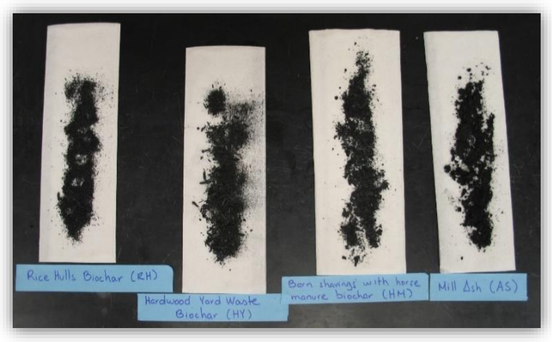
- The sugarcane industry is one of the most important contributors to Florida's agricultural economy.
- Likely expansion of sugarcane production into less productive **sandy soils** located northwest of the Everglades Agricultural Area (EAA) which are characterized with very **low organic matter (OM) content**, **water holding capacity (WHC), and nutrient retention** that results in **lower yields**.
- Use of agricultural and urban organic residues as soil amendments has the potential to:

-Increase agricultural production by improving soil properties
-Improve water quality through nutrient adsorption
-Reduce waste and contribute to carbon sequestration.



MILL ASH soil amendment

BIOCHAR soil amendment



- The GOAL is to investigate **four organic amendments** for their potential use to **improve soil** physiochemical properties and **sugarcane productivity** in sandy soils of south Florida, while also providing an **alternative use for local residues** and **protecting water quality**.

METHODOLOGY

- Mill ash and three biochars were incorporated at 1% and 2% (by weight) in 70 gallon lysimeters to grow sugarcane.
- A control without amendment and a standard commercial practice of mill ash applied at 6% were also included.
- Experiment design was a randomized block including nine treatments and the control with four replications of each.
- Recommended fertilization was applied equally to treatments and control.

Treatment Identification	
Control	No amendment
AS6	Mill ash 6% (standard practice treatment)
AS1	Mill ash 1%
AS2	Mill ash 2%
RH1	Rice hulls biochar 1%
RH2	Rice hulls biochar 2%
HY1	Hardwood yard waste biochar 1%
HY2	Hardwood yard waste biochar2%
HM1	Barn shavings with horse manure biochar 1%
HM2	Barn shavings with horse manure biochar 2%

- Final number of millable stalks, stalk biomass, and sucrose content was determined at harvest.
- Grand growth period leaf tissue analysis.
- Monthly measurements plant growth (tiller count and top visible dewlap height) and water quality parameters.
- Three soil samples analyzed for pH, OM, total phosphorus (TP), available P, soil ammonium (NH_4), nitrate (NO_3), and cation exchange capacity (CEC).
- Results were analyzed with generalized linear model and lsmeans Tukey multiple comparisons.

OBJECTIVES

1. Determine the effects of mill ash and three biochars applied at two rates (1% and 2% w/w) on **sugarcane plant growth and yield.**
2. Evaluate the effectiveness of the amendments to improve **soil physiochemical properties** of sandy soils.
3. Evaluate the influence of the amendments on **drainage water nutrient composition.**

Figure 1. Monthly plant measurements of top visible dewlap (TVD) height.

RESULTS AND DISCUSSION

Feedstock and Biochar Characterization

Table 1. Feedstock and amendment chemical characterization.

	P	K	Ca	Mg	Zn	Mn	Cu	Fe	Al
Feedstock	mg/kg								
HY	1385	3710	14118	1256	27	40	6	289	445
HM	4953	9805	13675	3141	61	105	11	323	600
RH	10809	7485	1444	6209	76	96	2	97	49
Amendment									
HY biochar	3273	6411	27782	1727	61	228	52	43149	781
HM biochar	11988	17894	19210	4307	101	306	41	17026	1371
RH biochar	15423	14909	5302	7524	126	219	13	18251	312
Mill ash	8908	11401	37979	11593	162	267	89	3865	2040

- Biochar nutrient concentration was greater compared with the feedstocks.

Table 2. Physiochemical characteristics of the amendments.

	pH	OM	TC	TN	C:N	Db	WHC	CEC
		%	g/kg	g/kg	ratio	g/cm3	%	cmolc/kg
HY biochar	8.49	63.87	63.88	0.64	100:1	0.25	202	4.27
HM biochar	8.82	94.97	71.56	1.02	70:1	0.17	360	7.48
RH biochar	9.02	58.87	47.95	1.44	33:1	0.19	313	9.42
Mill ash	9.60	24.61	21.07	0.10	77:1	0.26	197	17.64

- All amendments have high pH and WHC.
- C:N ratio of the amendments was high, except for RH biochar which had greater total nitrogen (TN) and lower total carbon (TC) compared to the other biochars.
- Mill ash and RH biochar had the highest CEC.
- All amendments had high OM and low bulk density (Db), which are favorable characteristics that could enhance sandy soil properties.

Leaf Tissue Analysis

Table 3. Leaf nutrient composition at grand growth period sampling

	N	P	K	Ca	Mg	Si	Fe	Mn	Zn	Cu
	(%)						(mg/kg)			
Control	1.13 (VD)	0.22 (S)	1.21 (S)	0.24 (S)	0.12 (D)	0.14 (VD)	39.56 (VD)	46.32 (S)	15.33 (M)	3.5 (M)
AS6	1.05 (VD)	0.15 (VD)	1.21 (S)	0.14 (D)	0.09 (VD)	2.18 (H)	27.58 (VD)	9.30 (VD)	7.76 (VD)	0.42 (VD)
AS1	1.06 (VD)	0.17 (D)	1.23 (S)	0.20 (M)	0.10 (VD)	0.81 (SP)	30.44 (VD)	19.41 (M)	9.55 (VD)	1.62 (VD)
AS2	1.05 (VD)	0.16 (VD)	1.36 (SP)	0.17 (D)	0.08 (VD)	1.24 (H)	30.17 (VD)	12.02 (D)	9.30 (VD)	0.70 (VD)
RH1	1.03 (VD)	0.21 (M)	1.26 (S)	0.18 (D)	0.12 (D)	0.78 (S)	36.18 (VD)	31.96 (S)	10.99 (VD)	1.87 (VD)
RH2	1.05 (VD)	0.18 (D)	1.24 (S)	0.12 (D)	0.10 (VD)	1.43 (H)	30.59 (VD)	16.94 (M)	8.75 (VD)	0.66 (VD)
HY1	1.13 (VD)	0.20 (M)	1.39 (S)	0.24 (S)	0.10 (VD)	0.15 (VD)	40.67 (D)	30.19 (S)	14.47 (D)	3.56 (M)
HY2	1.12 (VD)	0.18 (D)	1.49 (SP)	0.25 (S)	0.09 (VD)	0.20 (D)	40.75 (D)	27.62 (S)	14.15 (D)	3.56 (M)
HM1	1.08 (VD)	0.19 (M)	1.52 (SP)	0.20 (M)	0.10 (VD)	0.22 (D)	40.39 (D)	28.88 (S)	12.33 (VD)	3.44 (M)
HM2	1.14 (VD)	0.17 (D)	1.54 (SP)	0.21 (M)	0.10 (VD)	0.44 (D)	40.90 (D)	28.66 (S)	13.26 (D)	3.54 (M)

CNL categories: Sufficient Plus (SP), Sufficient (S), Marginal (M), Deficient (D), and Very Deficient (VD).

- Leaf N, P, Mg, Fe, Zn, and Cu contents range between very deficient (VD) to marginal (M) values.
- N limitation is a great concern since it can negatively affect plant growth and uptake of other essential nutrients.
- Sugarcane grown with AS and RH had sufficient (S) to high (H) Si content, which had a positive significant correlation with biomass and sucrose yields.

Plant Growth and Yield

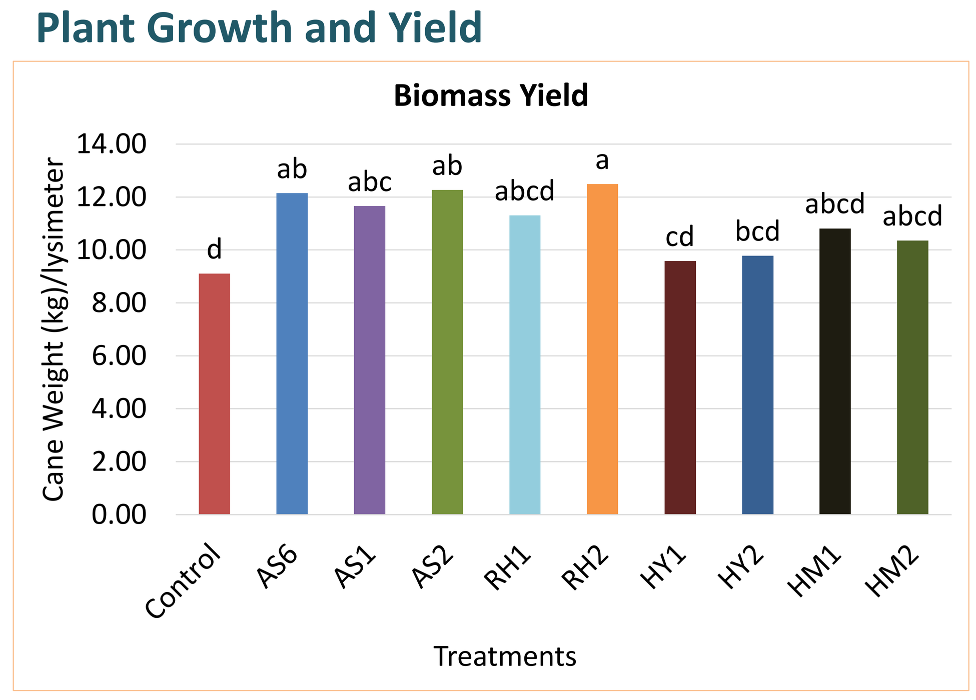


Figure 2. Biomass yield of plant cane harvest.

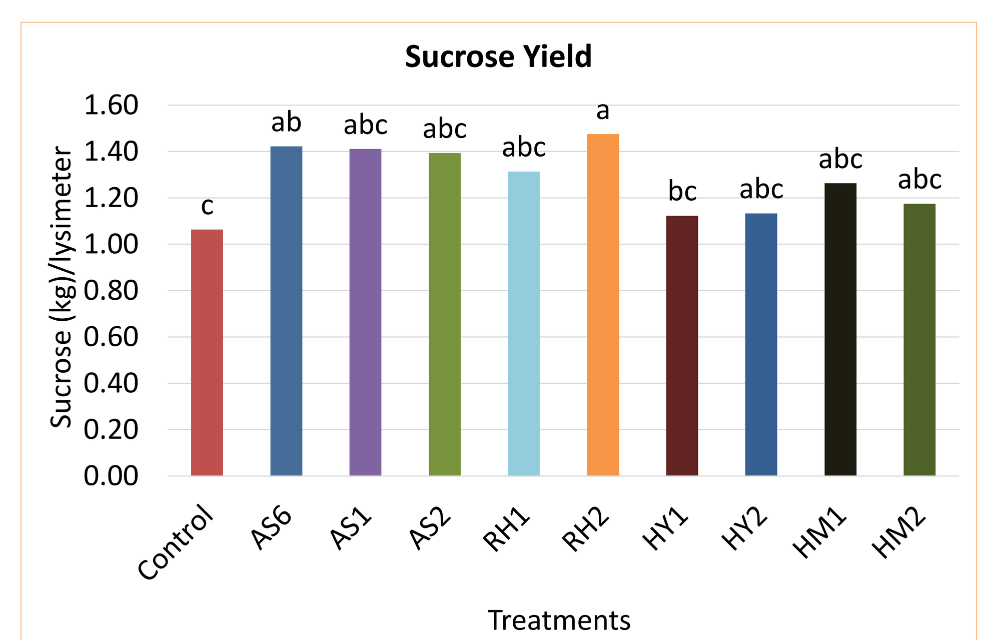


Figure 3. Sucrose yield of plant cane harvest.

- Compared with the control, application of RH2 resulted in 37% and 38% increase in biomass weight and sucrose yield, respectively.
- AS6 resulted in 33% increase of biomass weight and sucrose yields.
- Positive response with RH2 and AS6 could be due to higher nutrient availability and improvement in soil properties with the addition of these amendments,.

Soil Analyses

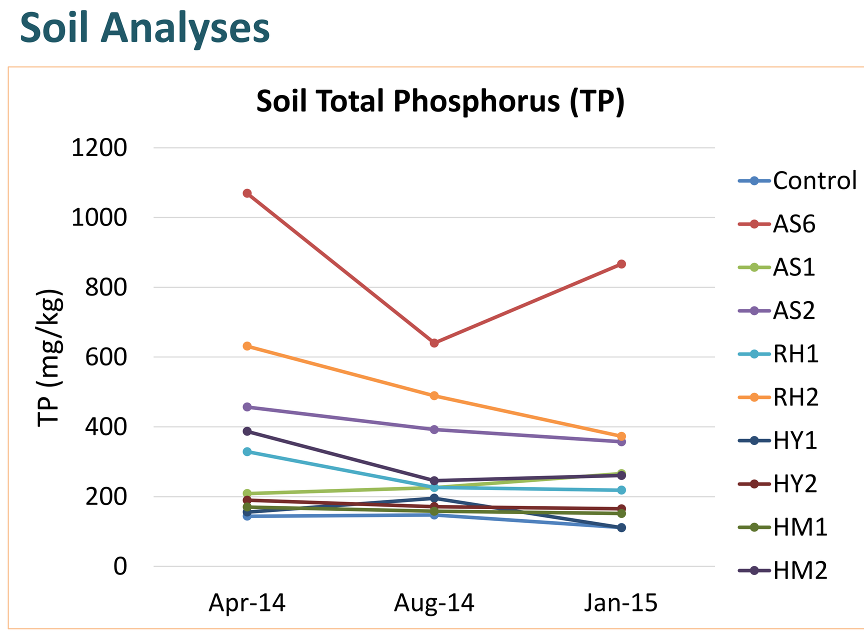


Figure 4. Total phosphorus of the soil over time.

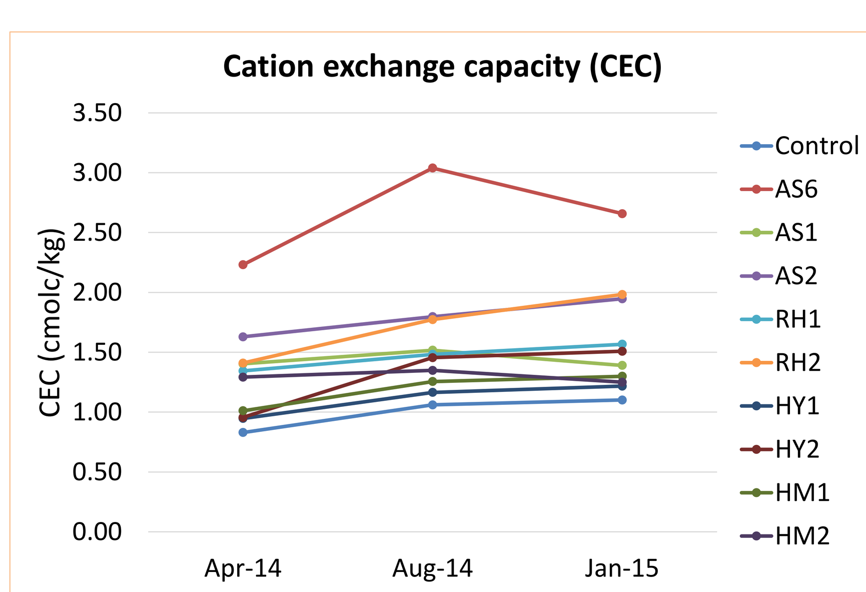


Figure 5. Cation exchange capacity of the soil over time.

- RH2 and AS6 had significantly greater TP and M3-P compared with the control throughout the experiment.
- RH2 significantly increased CEC over time, while soil amended with AS kept a constant CEC after 9 months.
- OM increased with application rates of 2% and AS6,. Also, OM did not significantly decrease over time showing the ability to increase stable OM.
- Soil pH shifted from slightly acidic to neutral or basic with treatment incorporation.

Water Analyses

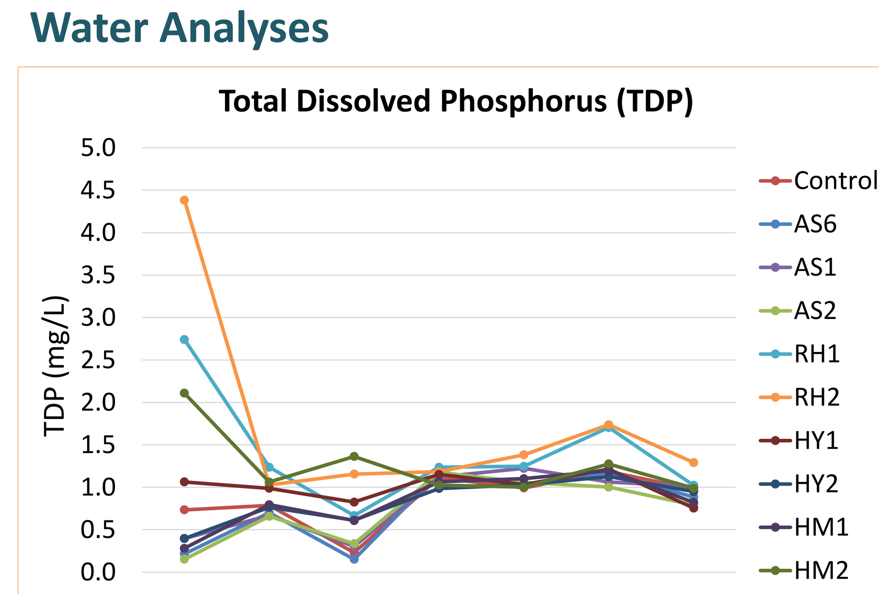


Figure 6. Total dissolved P in water over time.

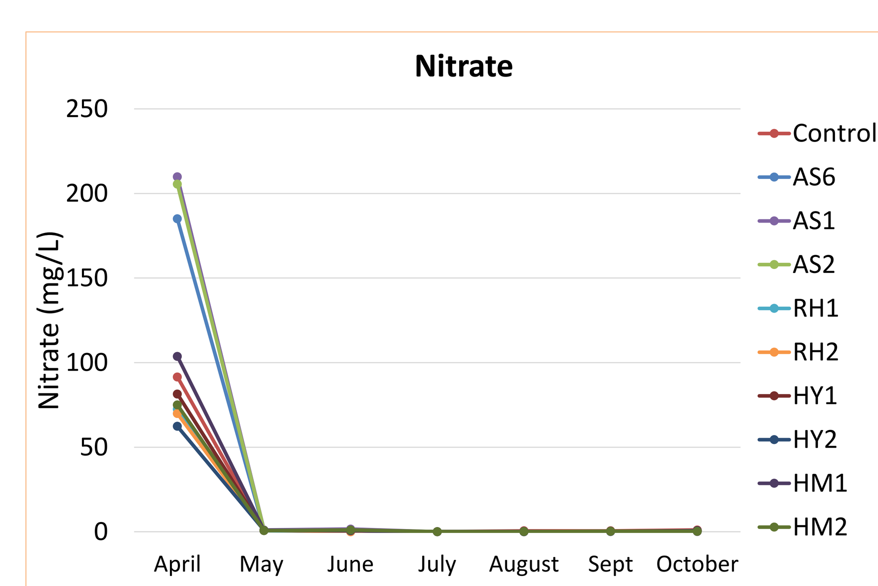


Figure 7. Nitrate in water over time.

- RH amendments had significantly higher TP, TDP, and SRP in comparison with the control and all treatments, except HM2. However, after April, there were no differences in P leaching compared with the control, which shows the amendments did not increase P release over time.
- Sharp decrease in nitrate and ammonium after first rainfall event displays a common issue in sandy soils of south Florida.

CONCLUSIONS

- Nutrient concentration was greater in the biochars compared to the feedstocks.
- RH biochar has greater potential to be used as a soil amendment for improving short-term nutrient availability due to its lower C/N ratio.
- RH2 and AS6 applications showed the most promising effects in terms of improving soil properties by adding available P and increasing CEC.
- The effects of RH2 and AS6 on soil properties and their supply of Si were probably the factors that most contributed to the enhancement of sugarcane yields in this experiment.
- Amendment incorporation to the sandy soil did not increase P or N leaching over time.
- Mill ash and the tree biochars used in this experiment had no negative effects on sugarcane growth or soil quality; but only RH2 and AS6 resulted in significant agronomic benefits and have the most potential to be used as soil amendments in sandy soils located northwest of the EAA.

FUTURE RESEARCH

- Study the use of AS and RH amendments over several ratoon crops in a field experiment.
- Evaluate the effects of nutrient retention, leaching, and runoff at the field scale.
- Economic analysis with costs of pyrolysis to process biochars, and costs of rate applications and spreading for both mill ash and biochars.
- Estimate the possible losses of amendment during application due to wind erosion, and assess safety issues during handling.