POTENTIAL BENEFITS OF BIOCHAR APPLICATION TO TROPICAL SOILS:
greenhouse gas emissions, soil improvement and crop yield

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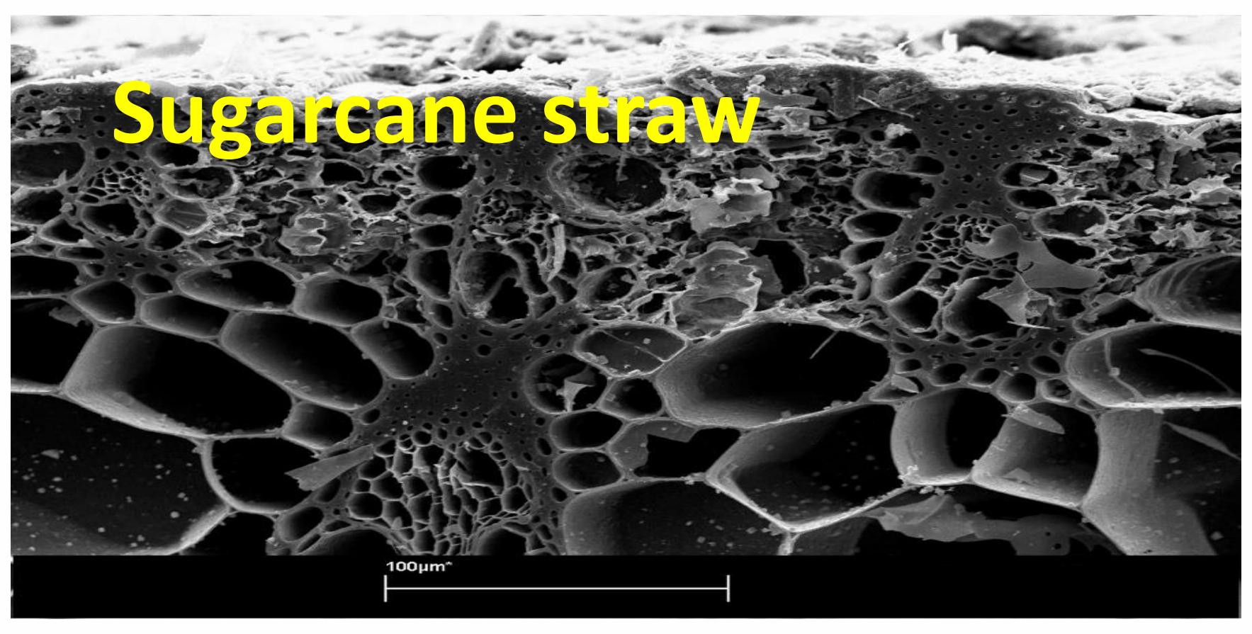
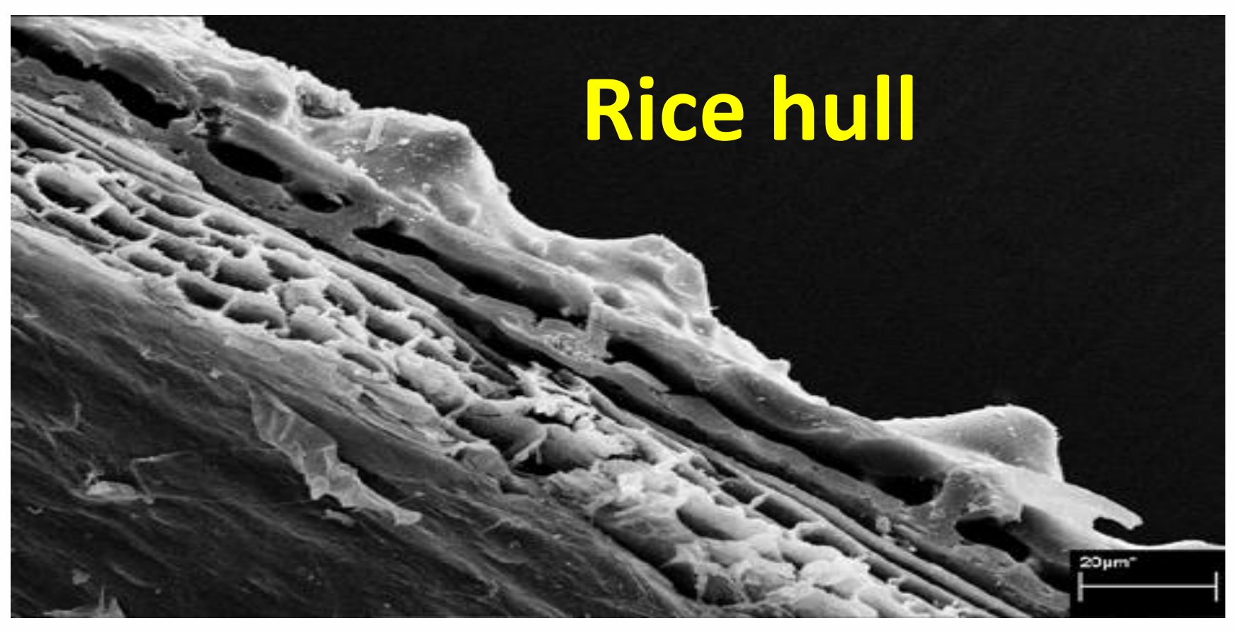
Introduction

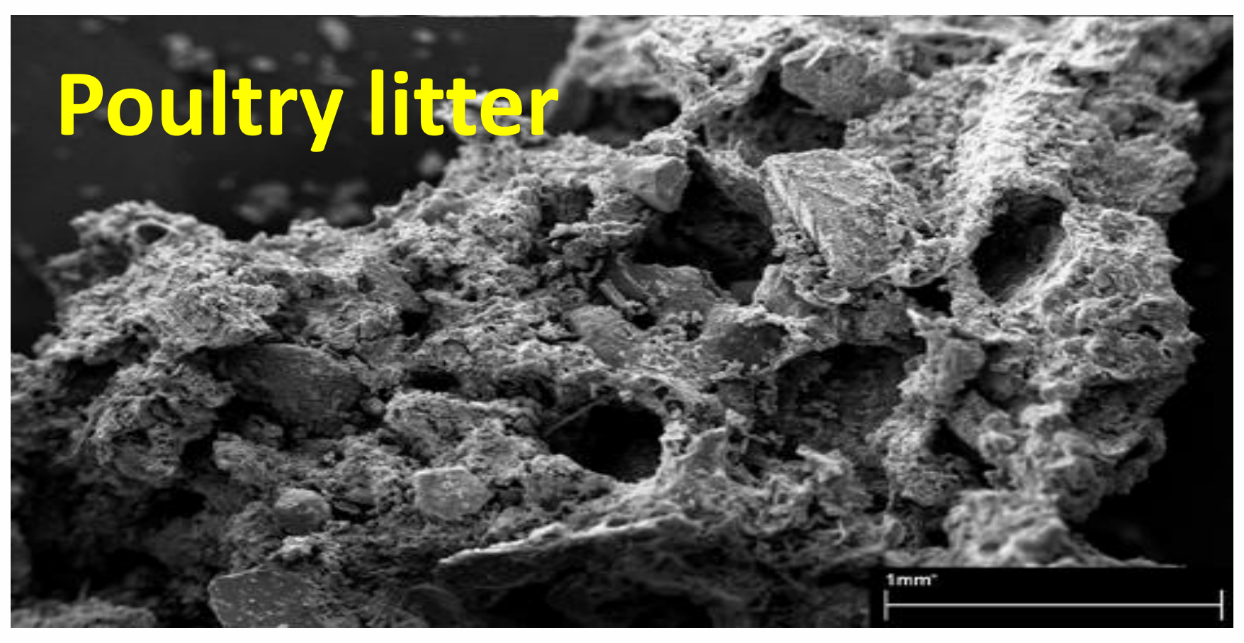
Researchers are pointing out the importance of greenhouse gas (GHG) emission reduction and increase carbon sequestration in the soil. Biochar, the solid product of pyrolysis, has been proposed as part of agronomic and environmental management to simultaneously improve soil properties and address climate mitigation. Although research on biochar has now accumulated an appreciable volume of data regarding effect of biochar in GHG emissions, soil properties and crop yields specially in temperate conditions, much less has been done for addressing these questions in tropical conditions.

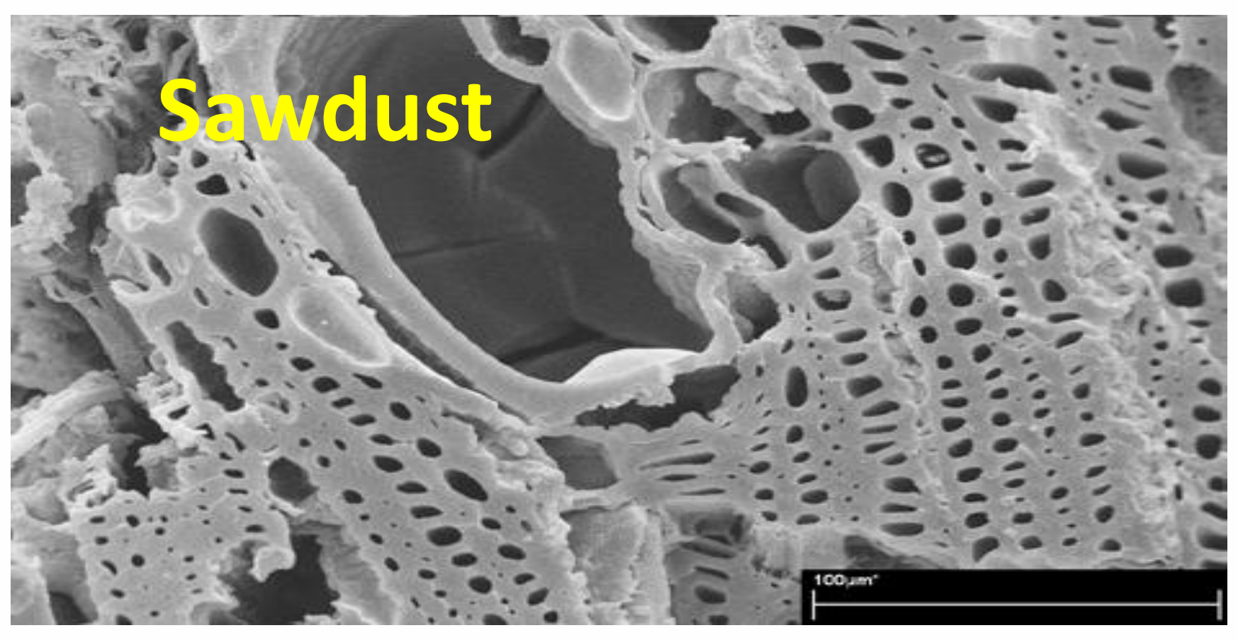
Material and Methods

This study evaluated the benefits of applying biochar to soils under laboratory incubations under controlled conditions, ii) greenhouse pot experiments and iii) cultivation of sugarcane in field conditions in a sandy tropical soil. We used biochar produced from different organic materials (poultry litter, sugarcane straw, rice hull, sawdust and *Miscanthus*) pyrolysed at final temperatures of 350˚C, 450˚C, 550˚C and 650˚C. The effect of temperature and feedstock type on the variability of physicochemical properties of biochars was evaluated through measurements of pH, electrical conductivity, cation exchange capacity, macronutrient content, proximate and elemental analyses, Fourier transform infrared spectroscopy, thermogravimetric analyses, GHG emissions and biological analyses. We assess not only aspects related to the mitigation of GHG emissions to the atmosphere, but also changes in soil chemical, physical and biological attributes and crop productivity.









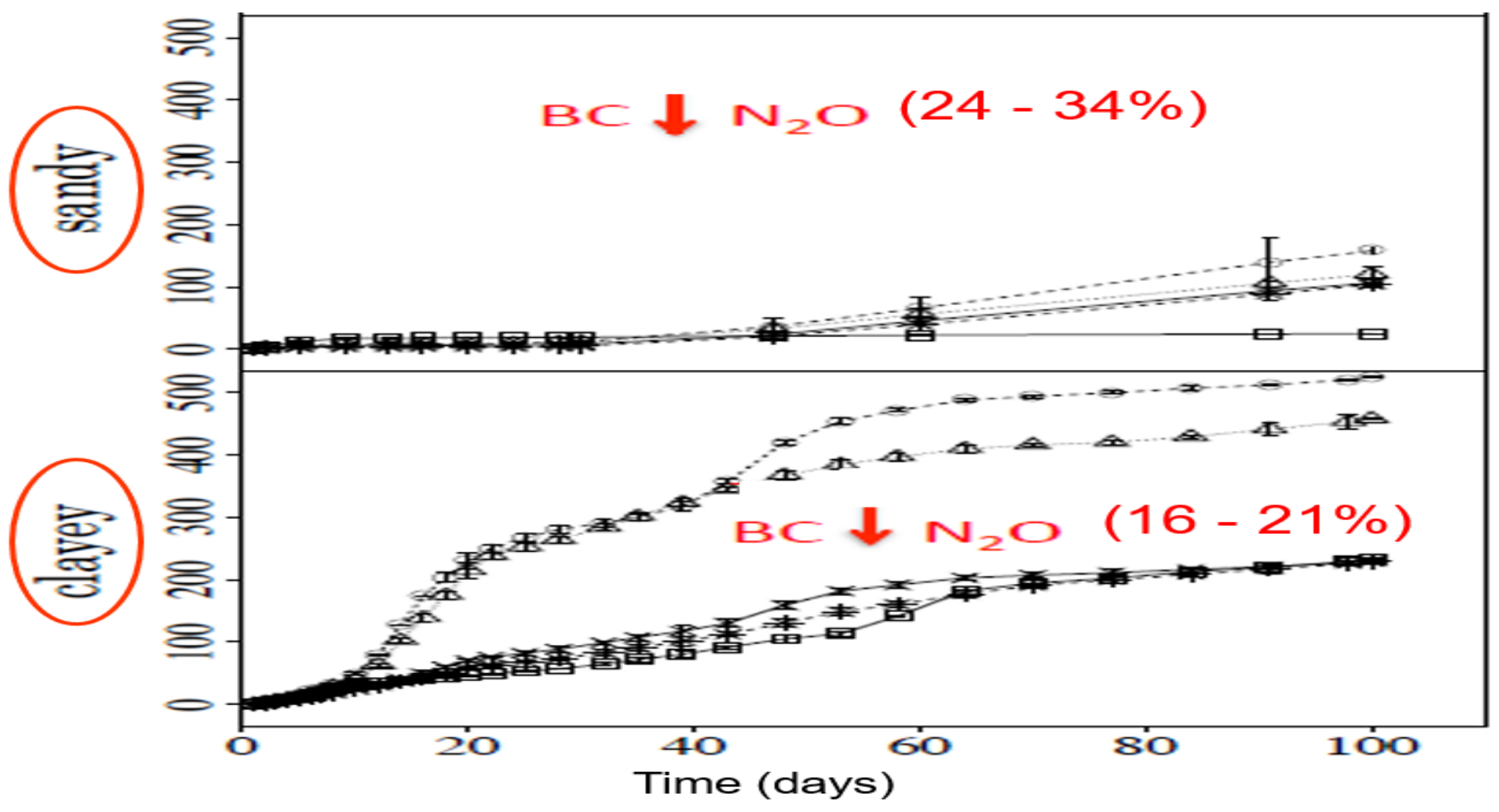
Results and Discussion

This study demonstrated how pyrolysis reaction affects biochar properties depending on the temperature range and the feedstock type. During pyrolysis, contrasting feedstock showed similar trends, such as the increase in pH values, and the concentration of macronutrients such as P, K, Ca and Mg. The extent of these trends however, occurred differently. Stability indicators showed same results, where release of O and H, while accumulation of C were influenced by the initial contents of such elements in each of the feedstocks. The use of sugarcane straw biochar as C sequestration strategy is encouraged in this study, considering that CO_2eq emissions of biochar treated soils were similar to soil-only treatments. Further analysis should be carried to investigate the potential of sugarcane biochar as a nutrient source in cropping systems. Overall these results demonstrate the potential of biochar as soil amendment.

Basic characteristics of biochar and respective feedstock

Feedstock		Temperature of Pyrolysis (°C)				
		350	450	550	650	
EC ($mS{\cdot}m^{-1}$)						
SC(1)	1.8	1.2 b(2)	1.4 b	2.0 b*(3)	1.9 b*	$y = 0.3025 + 0.0027x$ ($r^2 = 0.797; p = 0.0003$)
RH	0.8	0.2 a	0.2 a	0.3 a	0.3 a	ns(4)
PL	11.4	4.4 c	3.9 c	3.8 c	4.0 c	$y = 8.4609 - 0.0174x + 1.6 \times 10^{-5}x^2$ ($r^2 = 0.997; p = 0.0334$)
SD	0.4	0.1 a	0.1 a	0.1 a	0.1 a	ns
pH						
SC	7.8	8.7 d*	8.8 c*	9.1 c*	9.2 c*	$y = 8.0200 + 0.0018x$ ($r^2 = 0.907; p < 0.0001$)
RH	6.1	8.4 c*	8.3 b*	8.7 b*	8.7 b*	$y = 7.9275 + 0.0012x$ ($r^2 = 0.617; p < 0.0001$)
PL	7.3	8.2 b*	9.8 d*	9.8 d*	9.9 d*	$y = -1.5314 + 0.0404x - 3.5 \times 10^{-5}x^2$ ($r^2 = 0.931; p < 0.0001$)
SD	4.0	7.6 a*	7.0 a*	7.4 a*	7.5 a*	$y = 11.2748 - 0.0164x - 1.6 \times 10^{-5}x^2$ ($r^2 = 0.625; p < 0.0001$)
CEC ($mmol_c{\cdot}kg^{-1}$)						
SC	190	280 bc	200 c	166 b	169 b	$y = 878.896 - 2.436x - 0.0021x^2$ ($r^2 = 1.00; p = 0.0425$)
RH	77	158 a	166 ab	171 b	165 ab	ns
PL	597	320 c*	203 c*	106 b*	105 ab*	$y = 533.6833 - 0.6604x$ ($r^2 = 0.929; p < 0.0001$)
SD	303	207 ab	113 a*	86 a*	91 a*	$y = 901.9854 - 2.8627x - 0.0025x^2$ ($r^2 = 0.994; p = 0.0160$)

(1)SC = sugarcane straw, RH = rice husk, PL = poultry litter, SD = sawdust. (2)Means followed by the same letter are not different for biochars in the same pyrolysis temperature by Tukey's test 5%. (3)Means followed by an asterisk refer to differences between each biochar and its respective original biomass by Dunnett's test 5%. (4)Regression analysis was not significant for linear model.



. Cumulative CO_2-eq emissions, total C and N and EC from clayey soil incubated with sugarcane and poultry litter biochars pyrolysed at 350°C and 650°C.

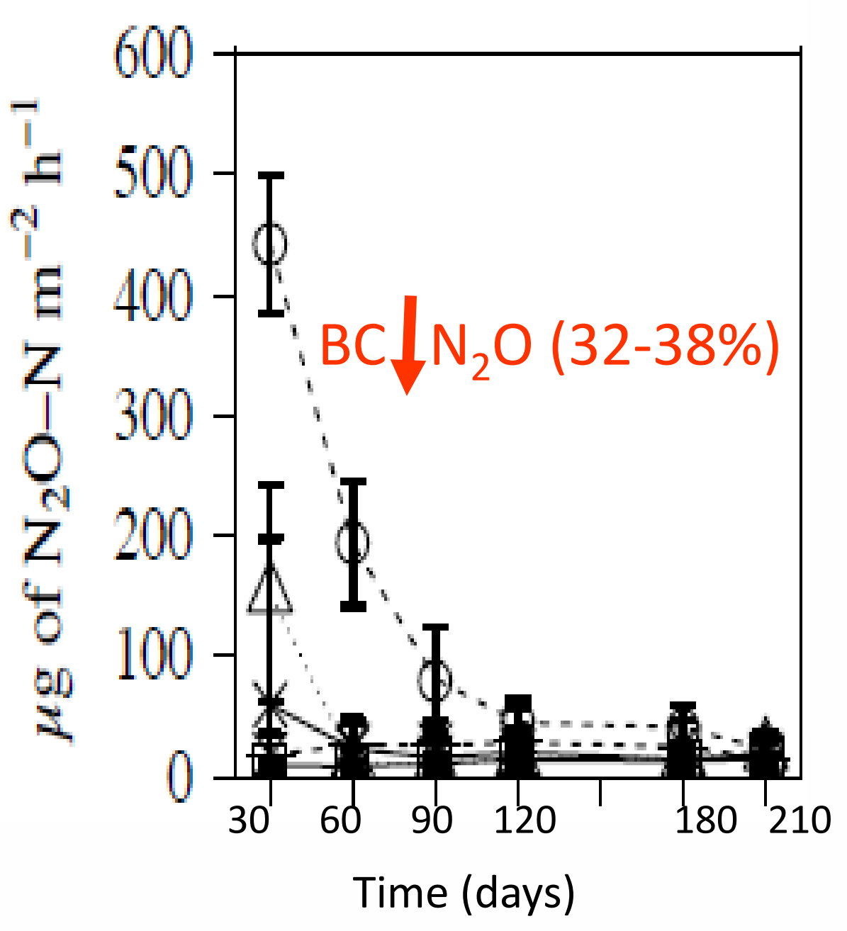
Feedstock	Pyrolysis Temp.	CO_2 eq cumulative ($mg{\cdot}kg{\cdot}soil^{-1}$)	Total N (%)	Total C (%)	EC ($mS{\cdot}m^{-1}$)
Typic Hapludox					
SC(1)	350°C	153.94 ± 16.1	0.43 ± 0.01*(2)	5.38 ± 0.04*	134.70 ± 4.12*
	650°C	153.52 ± 24.55	0.40 ± 0.03*	5.40 ± 0.18*	114.30 ± 4.43
PL	350°C	251.01 ± 43.89*	0.51 ± 0.02*	4.76 ± 0.09*	242.61 ± 19.37*
	650 °C	163.12 ± 29.62	0.39 ± 0.01*	4.90 ± 0.09*	236.07 ± 18.40*
Control		185.55 ± 35.7	0.29 ± 0.01	2.92 ± 0.06	106.08 ± 19.42
Quartzipsament					
SC	350°C	163.45 ± 34.94	0.19 ± 0.01*	3.09 ± 0.21*	82.42 ± 2.31*
	650°C	129.82 ± 13.22	0.14 ± 0.03*	2.74 ± 0.06*	94.91 ± 1.40*
PL	350°C	348.95 ± 47.49*	0.24 ± 0.01*	2.41 ± 0.11*	231.17 ± 11.44*
	650°C	103.05 ± 38.79	0.13 ± 0.01*	2.58 ± 0.14*	253.48 ± 6.87*
Control		136.01 ± 22.81	0.09 ± 0.01	0.74 ± 0.08	28.20 ± 5.16

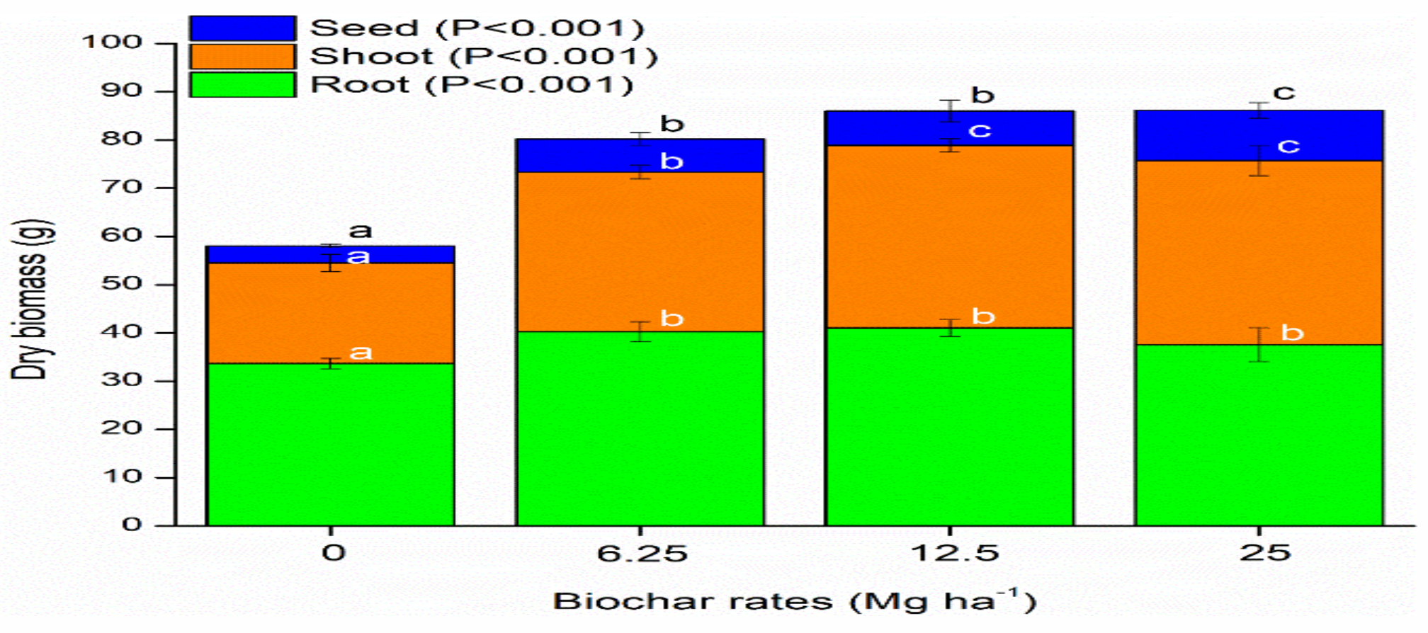
(1)SC = sugarcane straw, PL = poultry litter. (2)Means followed by an asterisk refer to differences between each biochar and its respective original biomass by Dunnett test 5%.

The biochar from poultry manure causes higher GHG emissions than the biochar produced from sugar cane straw, but both cause a significant reduction in the CO2eq emission and represent an environmentally secure way of depositing residual material in the field.

For the poultry manure biochar, higher pyrolysis temperatures have a significant effect in reducing GHG emissions, however this was not observed for the biochar produced from sugar cane straw thus it is much more recalcitrant and is not affected by different managements.

There is a greater emission of the three gases when applying the intermediate rate, demonstrated by a greater microbial biomass in this treatment, nevertheless, the cause is still not well known and deserves to be furthered studied.





The application of sugarcane straw biochar to soil improved N availability and the efficiency with which N is acquired by the plant and converted to grain yield, thereby enhancing crop performance; and biochar amendment significantly reduced N2O emissions that result from the application of nitrogen fertilizer to soil.

Treatments: (Control) Soil, no N, no BC; (T1) Soil, with N, no BC; (T2) Soil, with N, BC 10 Mg ha^{-1}, (T3) Soil, with N, BC 20 Mg ha^{-1}; and (T4) Soil, with N, BC 50 Mg ha^{-1}.

Time	N§	K_2O¶	$P_2O_5^{\#}$	S¶	B^a
	Application rates ($kg\,ha^{-1}$) †				
Planting	30	30	90	10	1.0
2nd split fertilization ‡	45	30	..	..	..
3rd split fertilization ‖	45	..	..	..	..
Total	120	60	90	10	1.0

† Application rates following the “Recommendations for fertilizer and lime to the State of Sao Paulo”.

‡ 30 – 40 days after plant emergence.

‖ 60 – 70 days after plant emergence.

§ ^{15}N labelled ammonium nitrate ($NH_4^{15}NO_3$).

¶ Potassium sulphate (K_2SO_4) at planting and Potassium chloride (KCl) at 1st split application.

\# Triple superphosphate (TSP).

a Boric acid (H_3BO_3).