



Universidade de Brasília - UnB



AGRICULTURA MITIGADORA DE RESÍDUOS URBANOS: BIOCHAR DE LODO DE ESGOTO

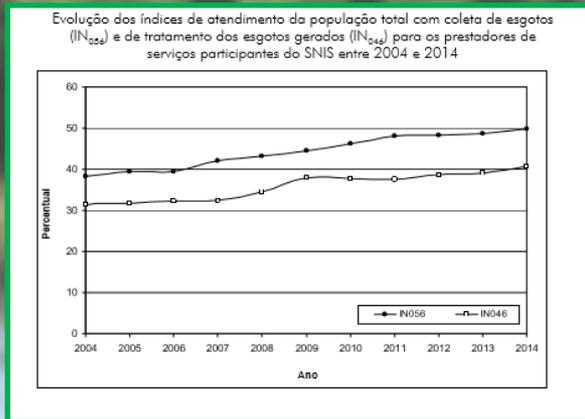
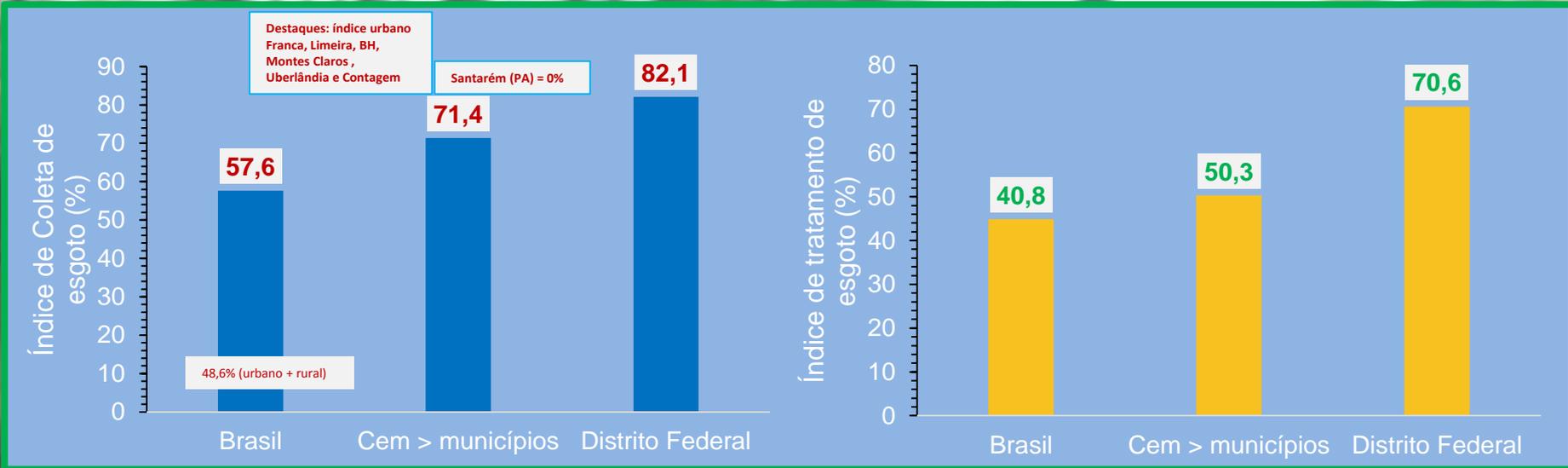
CÍCERO CÉLIO DE FIGUEIREDO

FACULDADE DE AGRONOMIA E MEDICINA VETERINÁRIA
UNIVERSIDADE DE BRASÍLIA



GOIÂNIA, OUTUBRO DE 2016

COLETA E TRATAMENTO DE ESGOTO NO BRASIL



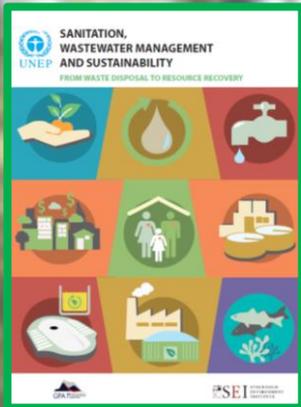
Fonte: SNIS (2014); Trata Brasil (2016)



- ✓ Mais de 100 milhões de brasileiros não têm acesso à coleta de esgoto
- ✓ Mais da metade das escolas brasileiras não têm acesso à coleta de esgoto
- ✓ 1,2 bilhão de m³ de esgoto lançados na natureza (2013).



DESTINO DO LODO DE ESGOTO NO BRASIL



E
A
P



?

?

BIOCHAR: DEFINIÇÃO E IMPORTÂNCIA

DEFINIÇÃO:

*Carbono pirogênico produzido por decomposição térmica de biomassa na ausência (ou limitada disponibilidade) de oxigênio e usado como um **condicionador do solo** para aumentar **a fertilidade e/ou sequestrar CO₂ atmosférico**.*

Carbono pirogênico para uso agrícola.

IMPORTÂNCIA:

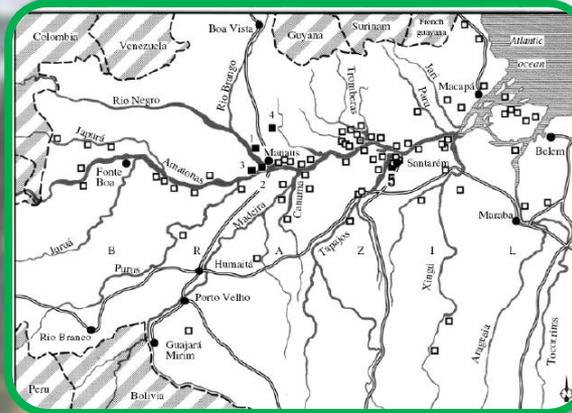
- ✓ Condicionador do solo (porosidade; retenção de água; adsorção de metais; nutrientes; efeito alcalinizante; biota do solo;
- ✓ Produtividade das culturas.
- ✓ Ambientais (retenção e acúmulo de C no solo; redução das emissões de N₂O do solo, etc)

Novotny et al. (2015).

"INSPIRAÇÃO" DA TECNOLOGIA BIOCHAR - TPI



Terra Preta de Índio (TPI)



Propriedades	Latosolos amazônicos	Terra Preta de Índio
Corg (g kg^{-1})	16,4	38,9
Pdisponível (mg kg^{-1})	1,7	507
Ca + Mg ($\text{cmol}_c \text{ kg}^{-1}$)	1,4	9,4
pH	4,5	5,6
CTC ($\text{cmol}_c \cdot \text{Kg}^{-1}$)	8,2	17,4



TPI – COMO UM EXEMPLO HISTÓRICO DA CREDIBILIDADE CIENTÍFICA DA APLICAÇÃO DE BIOCHAR.

TPI – COMO REFERÊNCIA PARA OS EXPERIMENTOS COM BIOCHAR.

(PROF. THOMAS KUYPER)

EXPERIÊNCIAS COM BIOCHAR



Lighting the unit



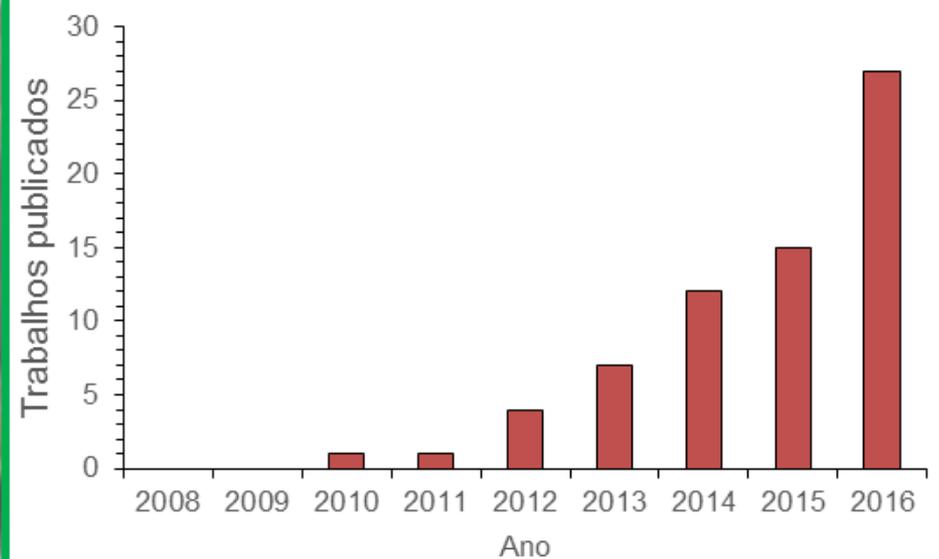
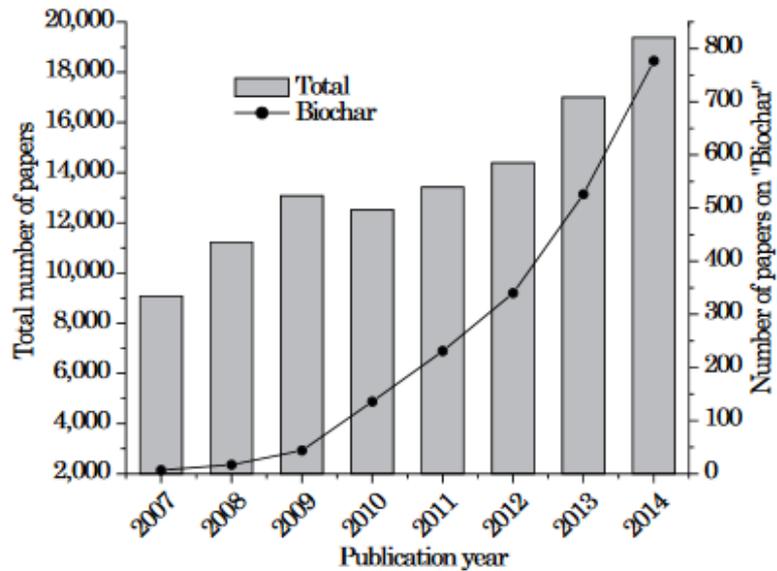
Transporting the unit



PRODUTOS COMERCIAIS



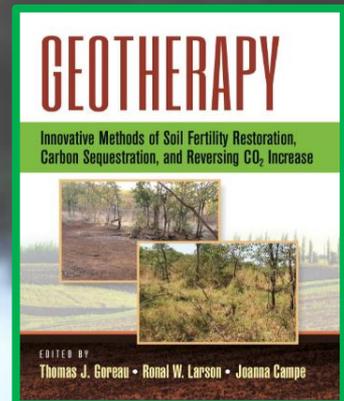
RELEVÂNCIA DO ASSUNTO 'BIOCHAR DE LODO DE ESGOTO'



Total = "black carbon/black C or pyrogenic carbon/pyrogenic C or charcoal"
Biochar = "biochar"

Termo utilizado "Biochar" and "Sewage Sludge"
Fonte: Science Direct, set/2016

Novotny et al. (2015)





PRODUÇÃO E CARACTERIZAÇÃO DO BIOCHAR

PROCESSO DE PIRÓLISE

Matéria-prima

RESÍDUOS ORGÂNICOS



LODO

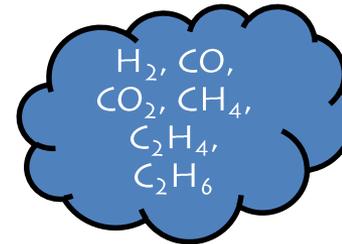


ETE

Forno de pirólise (reator)



Produtos da pirólise



GASES

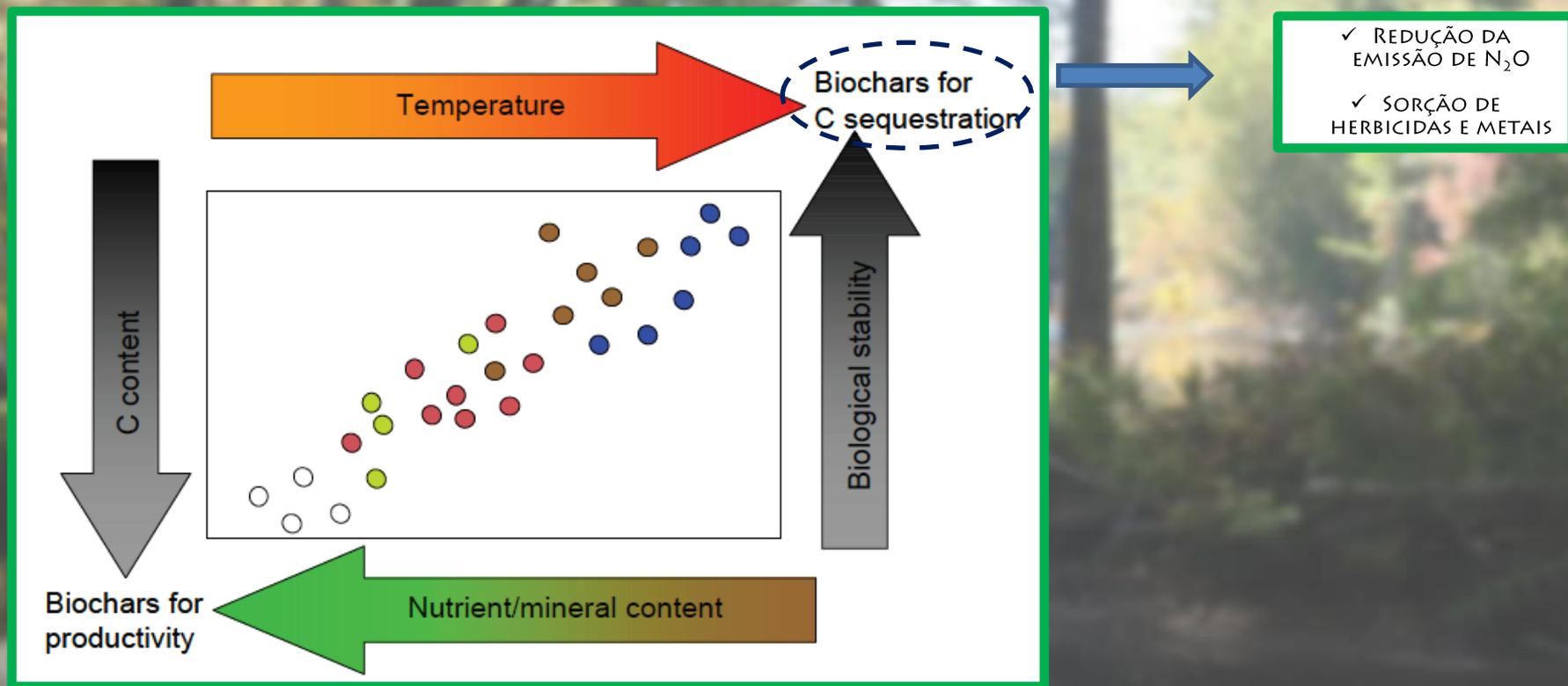


BIOCHAR



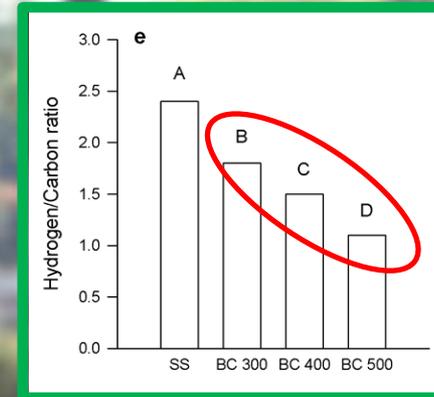
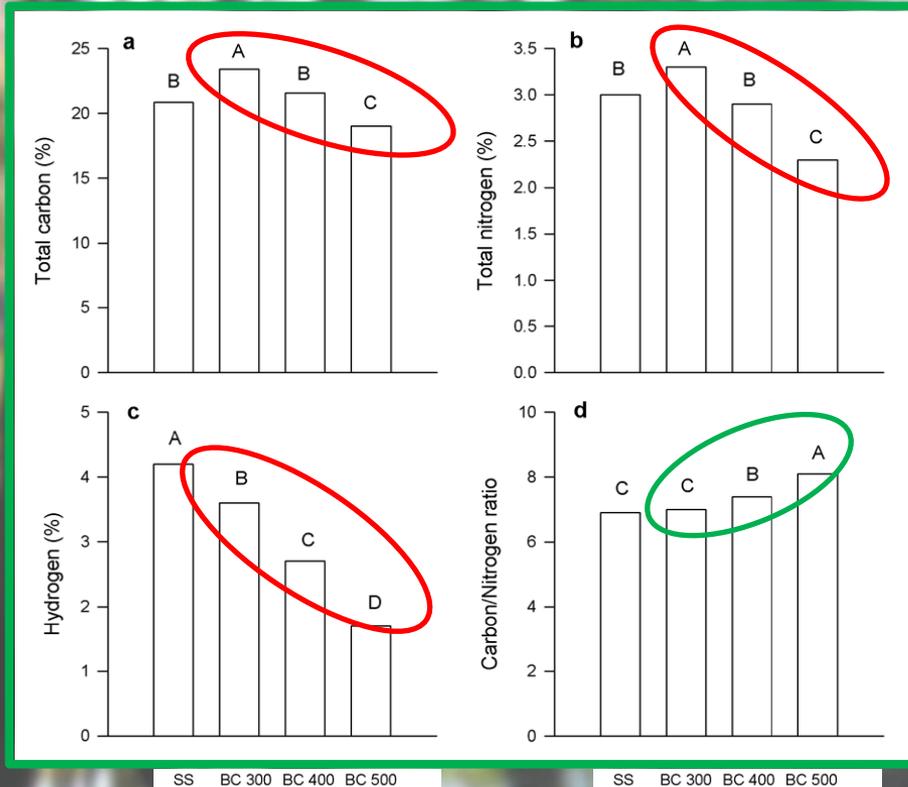
ÓLEO

AS PROPRIEDADES DO BIOCHAR VARIAM COM A TEMPERATURA DE PIRÓLISE



Adaptado de CSIRO (2015)

EFEITO DA TEMPERATURA DE PIRÓLISE NAS CARACTERÍSTICAS QUÍMICAS DE BIOCHAR DE LODO DE ESGOTO



Fonte: Figueiredo et al. (dados não publicados)

Sample	Yield (%)	C (%)	H (%)	N (%)	S (%)	H/C	C/N	pH	Ash (%)	SA _{N₂} m ² g ⁻¹
SS	/	26.52 ± 0.02e ^a	6.24 ± 1.50b	4.08 ± 0.03e	0.90 ± 0.19a	2.83	7.59	7.19 ± 0.06a	41.3 ± 0.1a	0.68
SSB ₄₀₀	60.57	21.90 ± 0.12d	1.85 ± 0.02a	3.10 ± 0.03d	0.85 ± 0.01a	1.01	8.23	8.46 ± 0.16b	64 ± 0.7b	5.49
SSB ₄₅₀	59.55	21.53 ± 0.31c	1.56 ± 0.02a	2.92 ± 0.01c	0.89 ± 0.02a	0.87	8.60	9.74 ± 0.10c	68 ± 0.1c	7.21
SSB ₅₀₀	59.01	21.24 ± 0.24bc	1.20 ± 0.00a	2.83 ± 0.15bc	0.84 ± 0.03a	0.68	8.76	9.75 ± 0.08c	69 ± 0.2d	7.73
SSB ₅₅₀	58.76	20.66 ± 0.22b	1.01 ± 0.02a	2.54 ± 0.11b	0.86 ± 0.01a	0.58	9.48	10.47 ± 0.02d	71 ± 0.2e	8.45
SSB ₆₀₀	53.09	19.88 ± 0.16a	0.71 ± 0.00a	2.04 ± 0.15a	0.87 ± 0.02a	0.43	11.37	11.7 ± 0.05e	74 ± 0.1f	5.99

SS, raw sewage sludge; SSB_x, biochar derived from sewage sludge pyrolysis at X (°C) temperature.

SA_{N₂}, the specific surface area determined using N₂ sorption isotherms.

^a Lowercase letters after the numerical values show significant differences within each column of data ($p < 0.05$, $n = 5$).

EFEITO DA TEMPERATURA DE PIRÓLISE NAS CARACTERÍSTICAS QUÍMICAS DE BIOCHAR DE LODO DE ESGOTO

SS/BC	Yield	pH	Ash content [%]	C [%]	H [%]	N [%]	O [%]	O/C	H/C	(O+N)/C
SSKN		7.08	55.83	21.6	4.22	3.52	14.83	0.52	2.34	0.66
BCKN500	54.29 ± 5.15	7.13	73.56	18.92	0.72	2.72	4.08	0.16	0.46	0.29
BCKN600	51.27 ± 5.11	11.04	77.77	18.43	0.38	2.24	1.19	0.05	0.25	0.15
BCKN700	48.66 ± 4.14	12.23	79.08	18.12	0.24	1.88	0.68	0.03	0.16	0.12
SSKZ		7.19	61.32	23.79	4.65	4.66	5.58	0.18	2.35	0.34
BCKZ500	50.37 ± 4.96	7.08	68.09	23.16	0.77	3.57	4.42	0.14	0.4	0.28
BCKZ600	46.40 ± 5.24	11.45	70.27	23.72	0.44	3.29	2.29	0.07	0.22	0.19
BCKZ700	43.69 ± 3.74	12.38	74.28	22.84	0.33	2.25	0.3	0.01	0.17	0.09
SSCM		7.01	58.08	22.68	3.76	3.62	11.86	0.39	1.99	0.53
BCCM500	54.45 ± 5.76	7.17	68.98	22.41	0.67	3	4.94	0.17	0.36	0.28
BCCM600	51.10 ± 4.89	11.33	70.22	22.47	0.63	2.67	4.02	0.13	0.34	0.24
BCCM700	49.46 ± 3.88	12.44	71.99	21.71	0.56	2.4	3.34	0.12	0.31	0.21
SSSI		7.39	58.49	26.23	5.1	5.74	4.44	0.13	2.33	0.32
BCSI500	45.07 ± 4.68	7.25	64.1	26.59	1.08	3.95	4.29	0.12	0.49	0.25
BCSI600	43.18 ± 3.30	8.05	63.86	27.68	0.82	3.76	3.89	0.11	0.36	0.22
BCSI700	40.20 ± 4.31	13.1	67.98	27.84	0.48	2.92	0.79	0.02	0.21	0.11

Fonte: Zielinska et al. (2015)

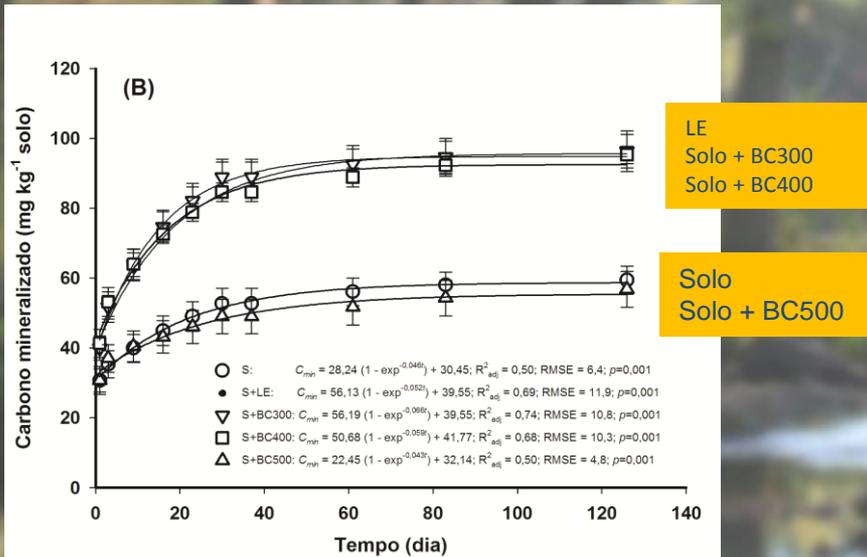
EFEITO DA TEMPERATURA DE PIRÓLISE NAS CARACTERÍSTICAS QUÍMICAS DE BIOCHAR DE LODO DE ESGOTO

Properties ¹	Units	SS ²	BC 300	BC 400	BC 500
Dry matter	g	830	714	627	543
RE			0.86	0.75	0.65
NO ₃ ⁻	mg kg ⁻¹	23.35	17.51	5.84	5.83
RE			0.75	0.25	0.25
NH ₄ ⁺	mg kg ⁻¹	461.2	431.9	198.5	169.3
RE			0.94	0.43	0.37
pH		4.8	5.8	6.5	6.5
RE			1.22	1.35	1.35
Phosphorus	g 100g ⁻¹	3.57	4.11	5.37	6.13
RE			1.15	1.50	1.72
Potassium	g 100g ⁻¹	0.08	0.106	0.108	0.125
RE			1.32	1.35	1.56
Calcium	g 100g ⁻¹	0.66	0.67	0.71	0.78
RE			1.01	1.07	1.18
Magnesium	g 100g ⁻¹	0.17	0.18	0.17	0.17
RE			1.06	1.00	1.00
Sulfur	g 100g ⁻¹	0.67	1.51	0.96	0.74
RE			2.25	1.43	1.10
SSA	m ² g ⁻¹	18.19	20.17	29.85	52.47
RE			1.11	1.64	2.88
PV	mL g ⁻¹	0.022	0.027	0.046	0.053
RE			1.23	2.09	2.41

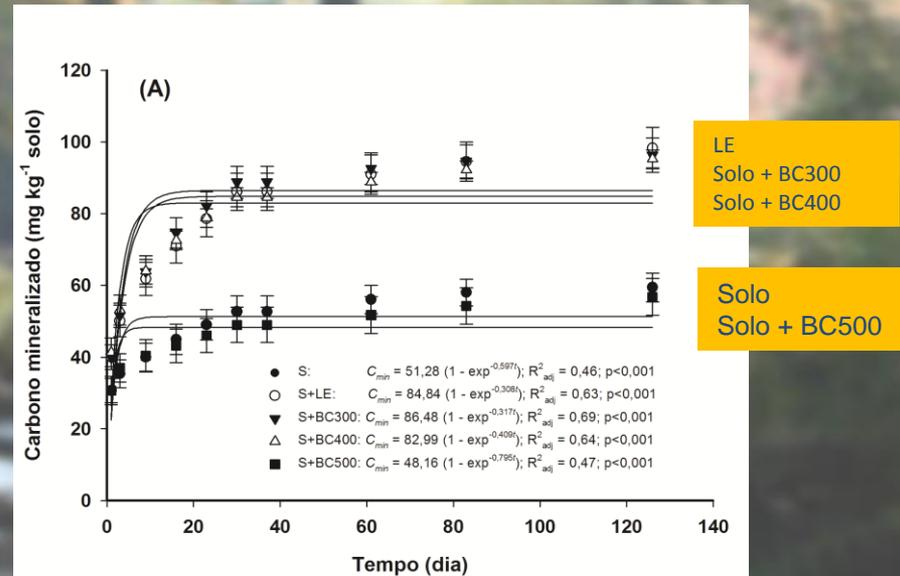
Fonte: Lopes (2015)

MINERALIZAÇÃO DO CARBONO DE BIOCHAR DE LODO DE ESGOTO

CINÉTICA DE MINERALIZAÇÃO DO BIOCHAR DE LE (MODELO E-PRIMEIRA ORDEM - JONES, 1984)



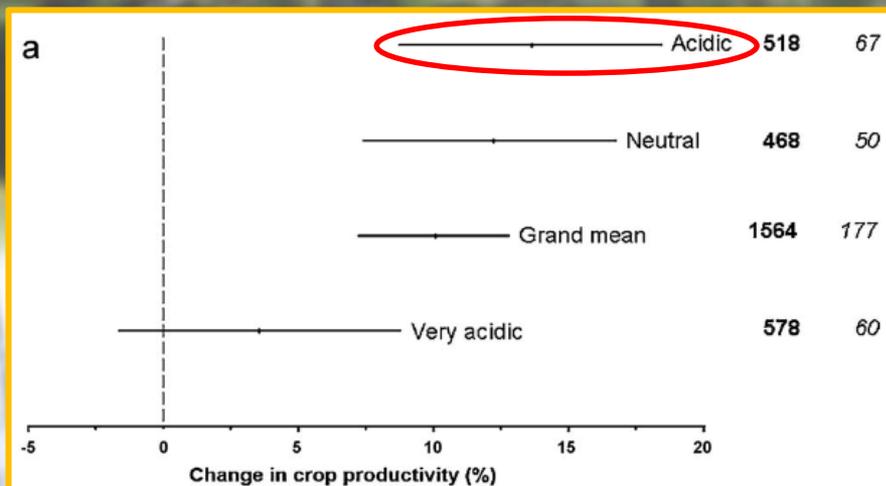
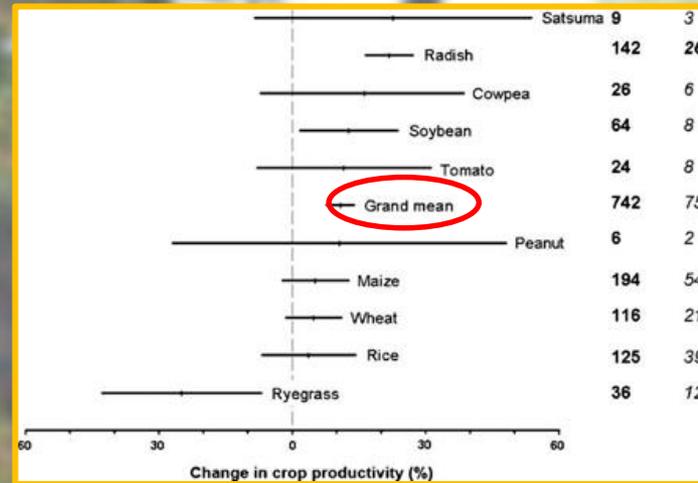
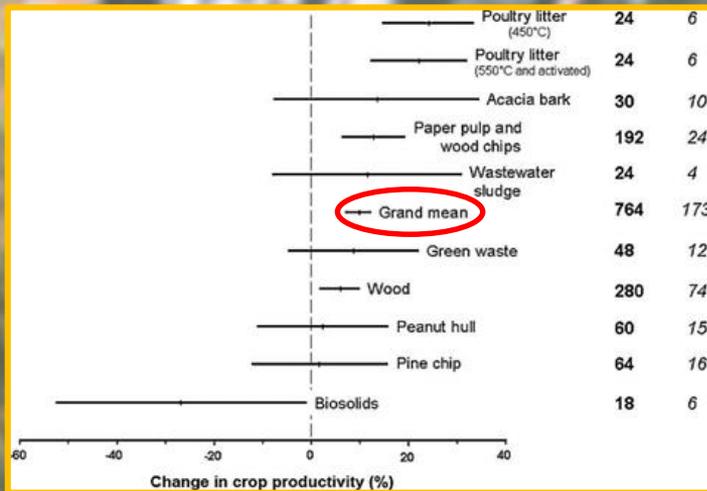
CINÉTICA DE MINERALIZAÇÃO DO BIOCHAR DE LE (MODELO PRIMEIRA ORDEM - MURWIRA ET AL., 1990)





USO DO BIOCHAR

EFEITOS GERAIS DA APLICAÇÃO DE BIOCHAR AO SOLO

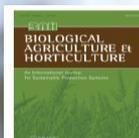
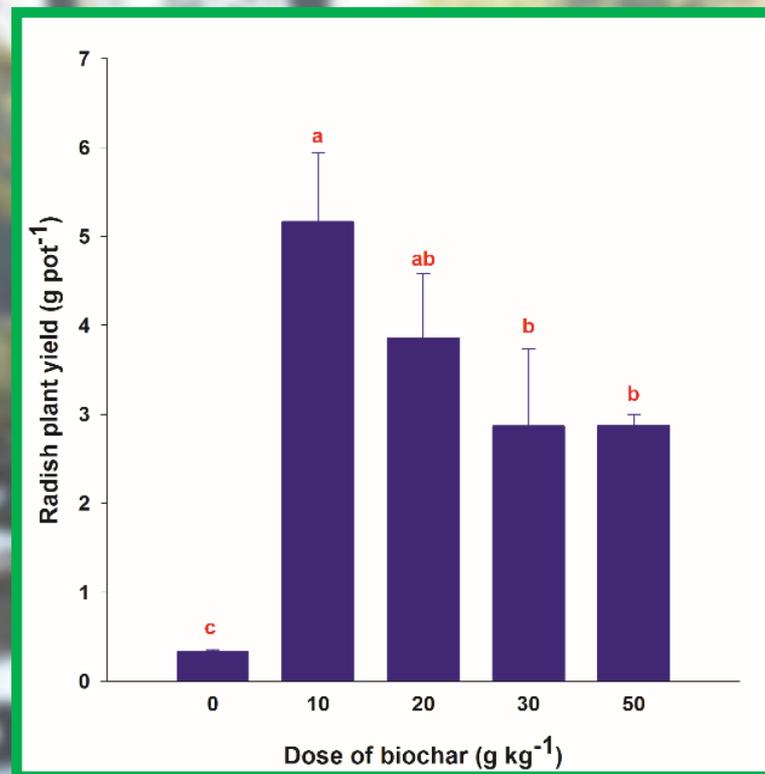


Review

A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis

S. Jeffery^{a,*}, F.G.A. Verheijen^{a,d}, M. van der Velde^{a,b}, A.C. Bastos^c

EFEITO DO BIOCHAR DE LODO DE ESGOTO NA PRODUÇÃO DE RABANETE



Biological Agriculture & Horticulture
An International Journal for Sustainable Production Systems

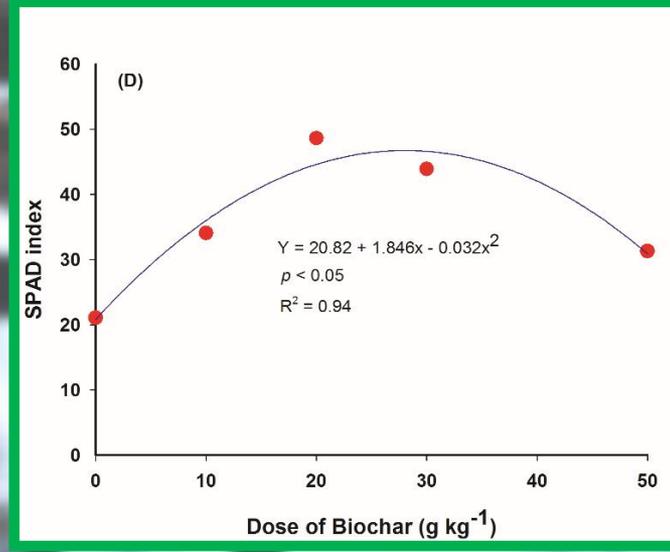
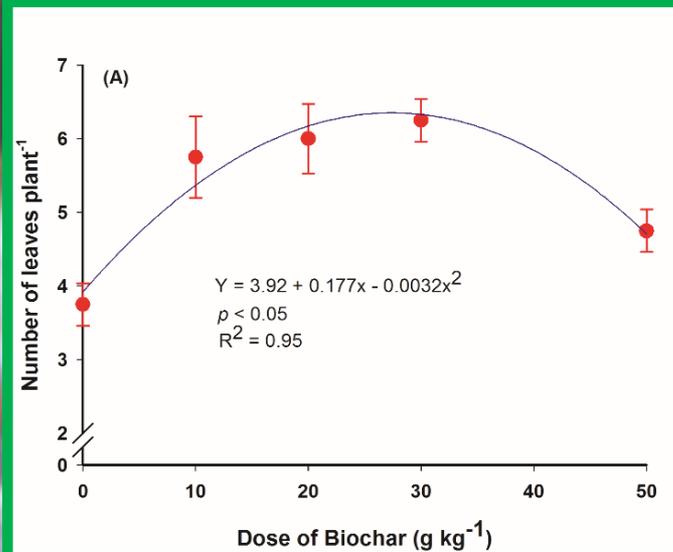
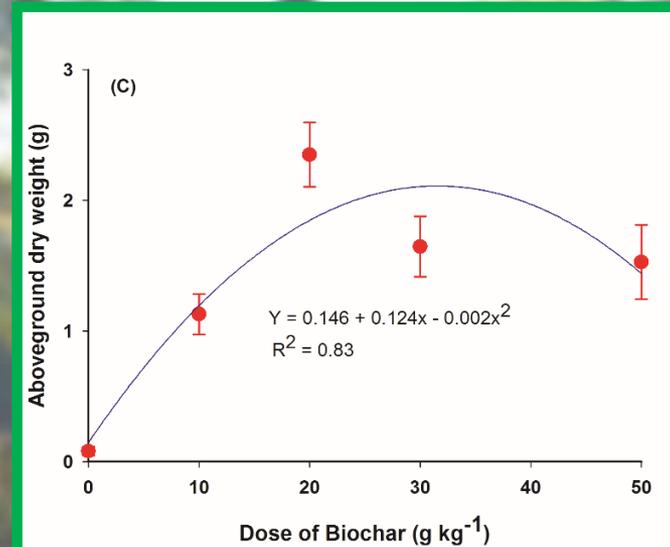
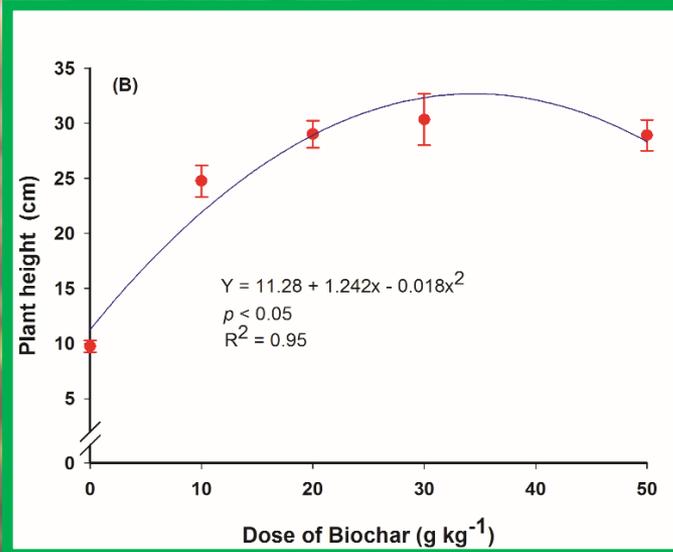


ISSN: 0144-8765 (Print) 2165-0616 (Online) Journal homepage: <http://www.tandfonline.com/loi/tbah20>

Sewage sludge biochar: effects on soil fertility and growth of radish

A. A. T. C. Sousa & C. C. Figueiredo

EFEITO DO BIOCHAR DE LODO DE ESGOTO NA PRODUÇÃO DE RABANETE



EXPERIMENTO DE CAMPO PARA AVALIAR OS EFEITOS DO BIOCHAR DE LODO DE ESGOTO NAS PROPRIEDADES DO SOLO E NA PRODUTIVIDADE DO MILHO



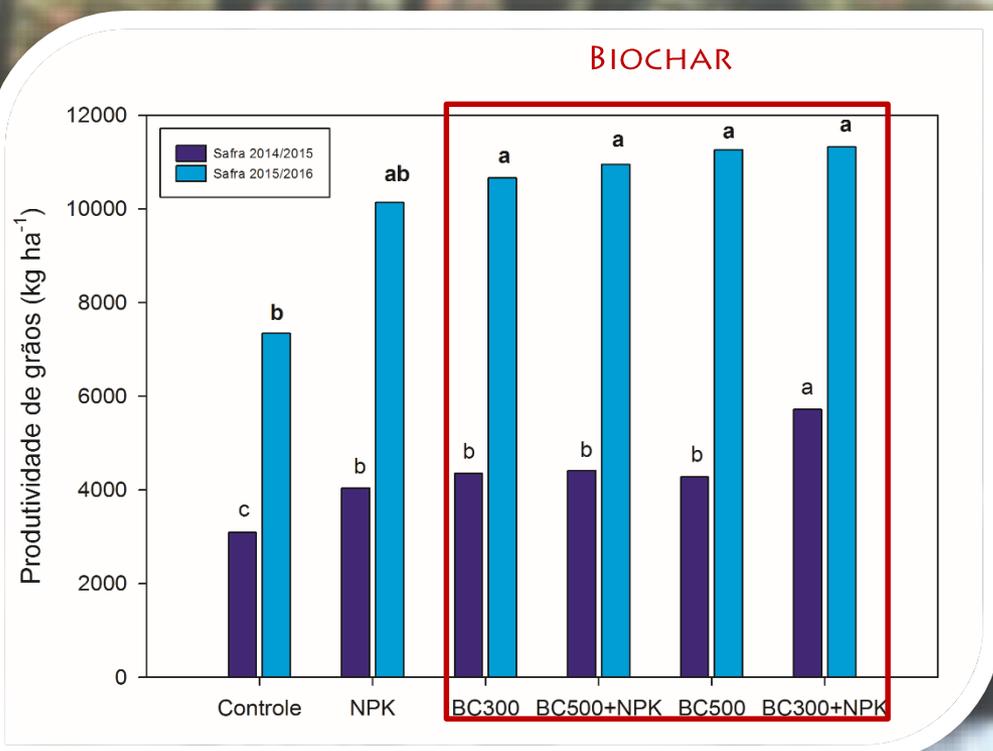
Safra 2014/2015



Safra 2015/2016



EFEITO DO BIOCHAR DE LODO DE ESGOTO NA PRODUTIVIDADE DE GRÃOS DE MILHO



Safra 2014/2015



Safra 2015/2016



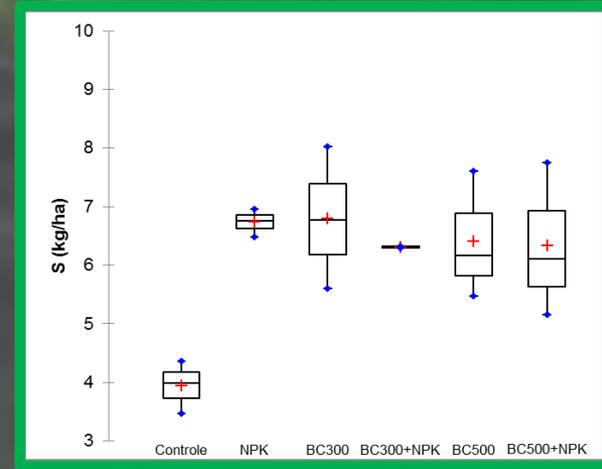
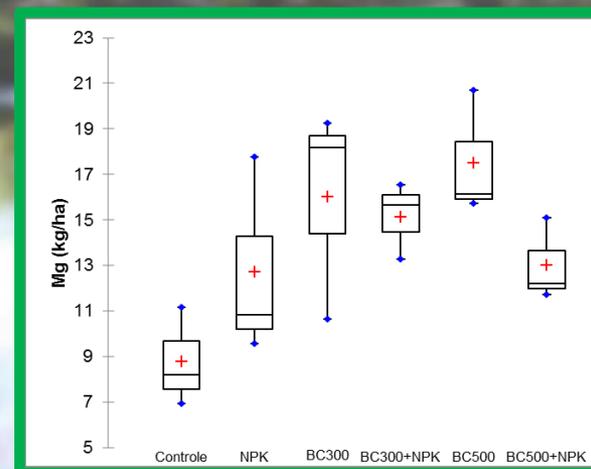
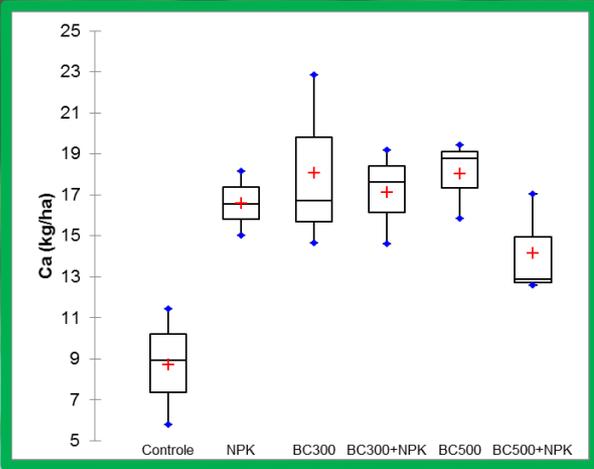
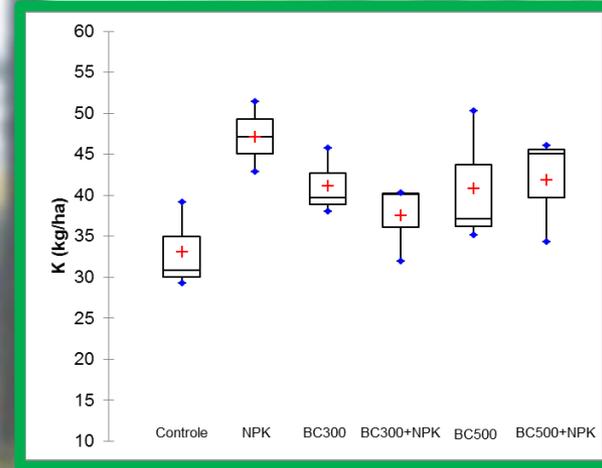
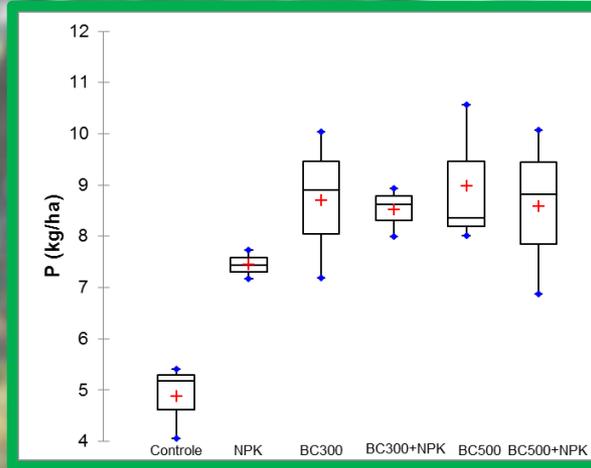
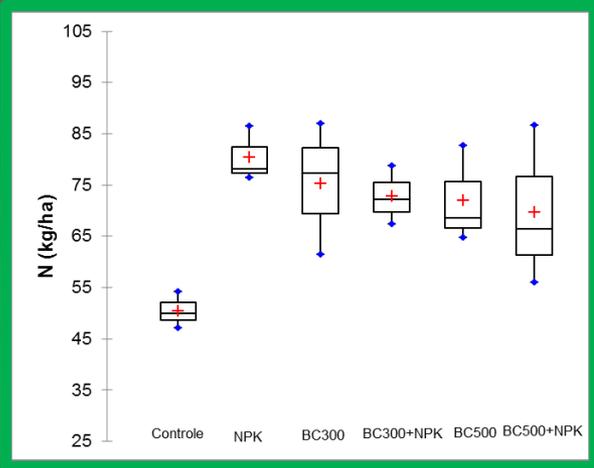
RESPOSTA DO MILHO AO BIOCHAR DE LODO DE ESGOTO

SEM BIOCHAR

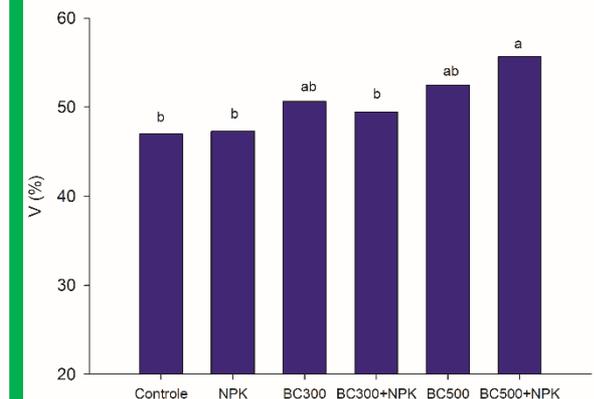
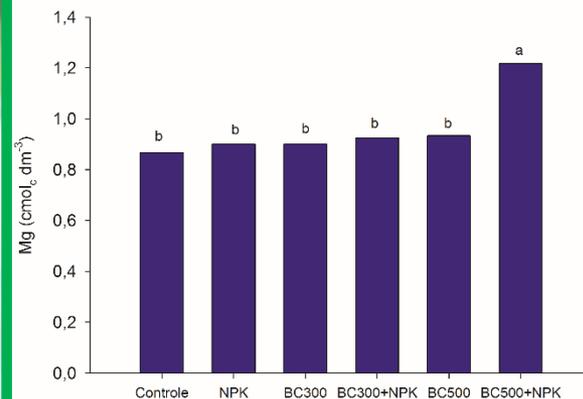
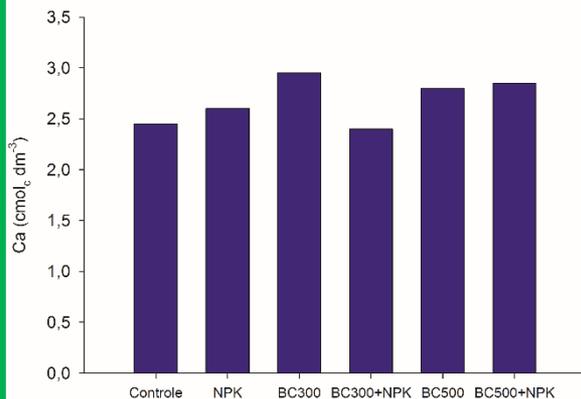
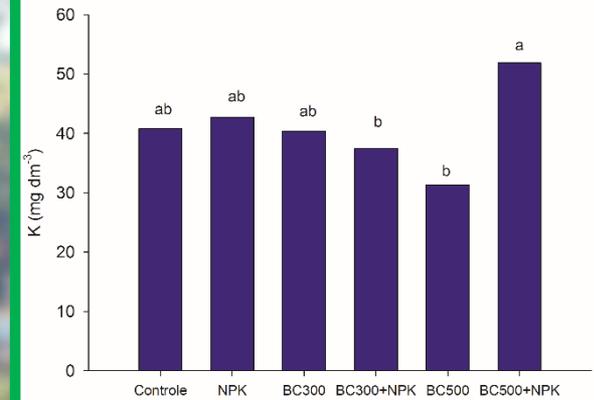
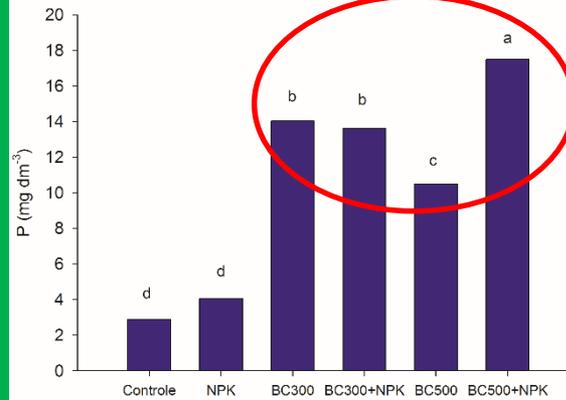
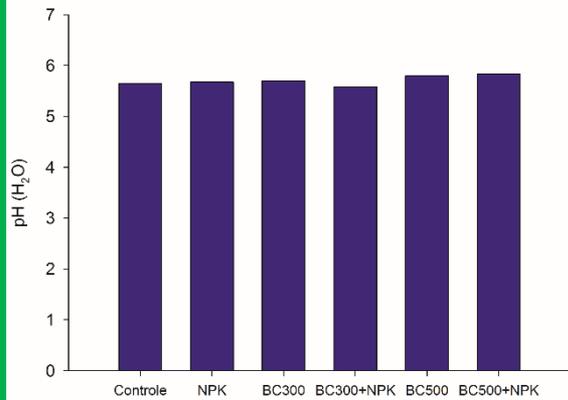
COM BIOCHAR



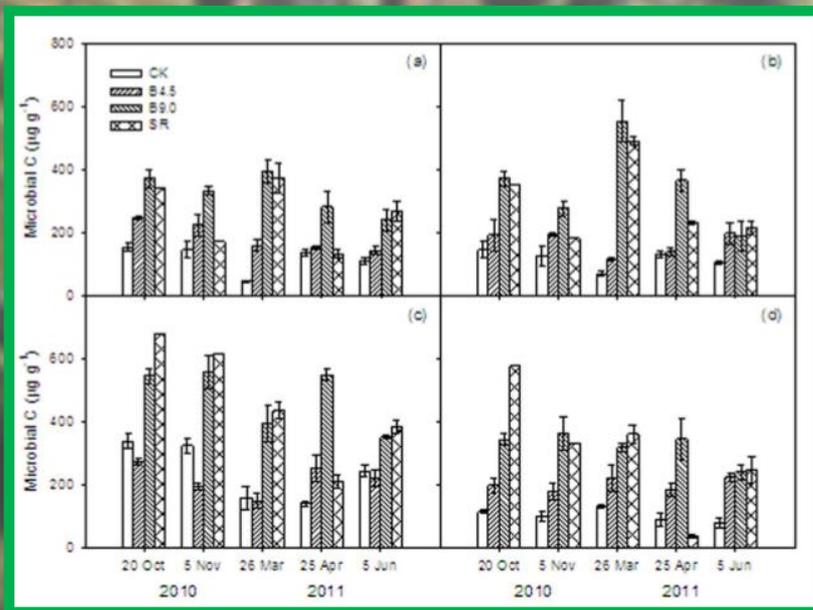
EFEITOS BIOCHAR DE LODO DE ESGOTO NA ABSORÇÃO DE NUTRIENTES PELO MILHO



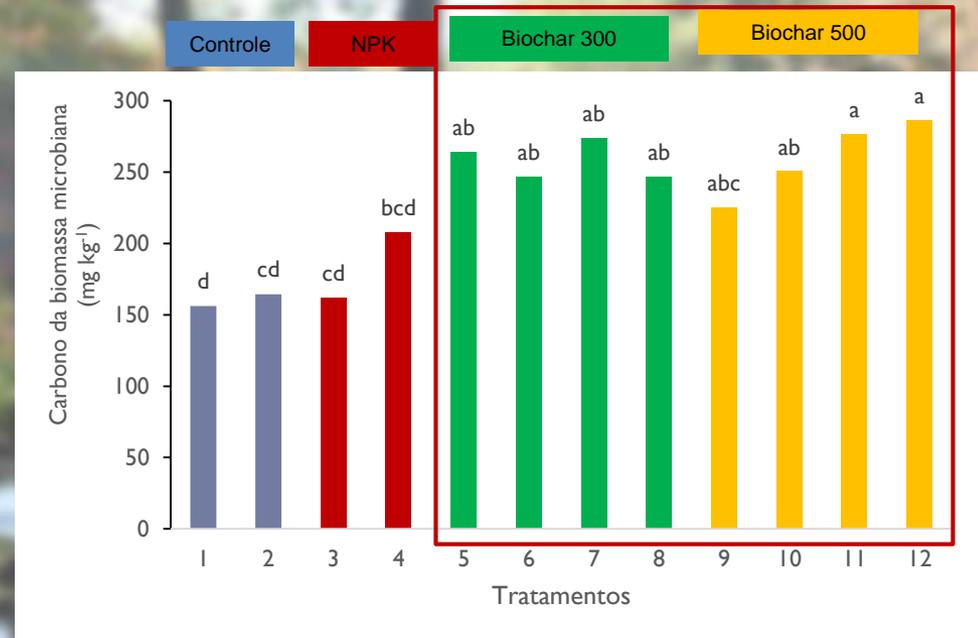
EFEITOS BIOCHAR DE LODO DE ESGOTO NOS INDICADORES DE FERTILIDADE DO SOLO



EFEITO DO BIOCHAR DE LODO DE ESGOTO NA MICROBIOTA DO SOLO

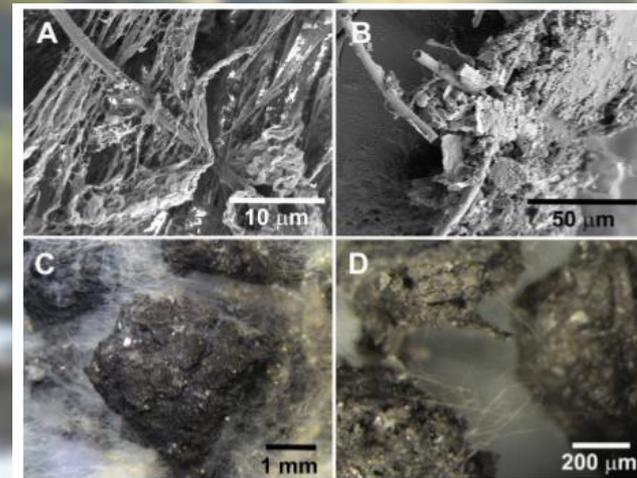
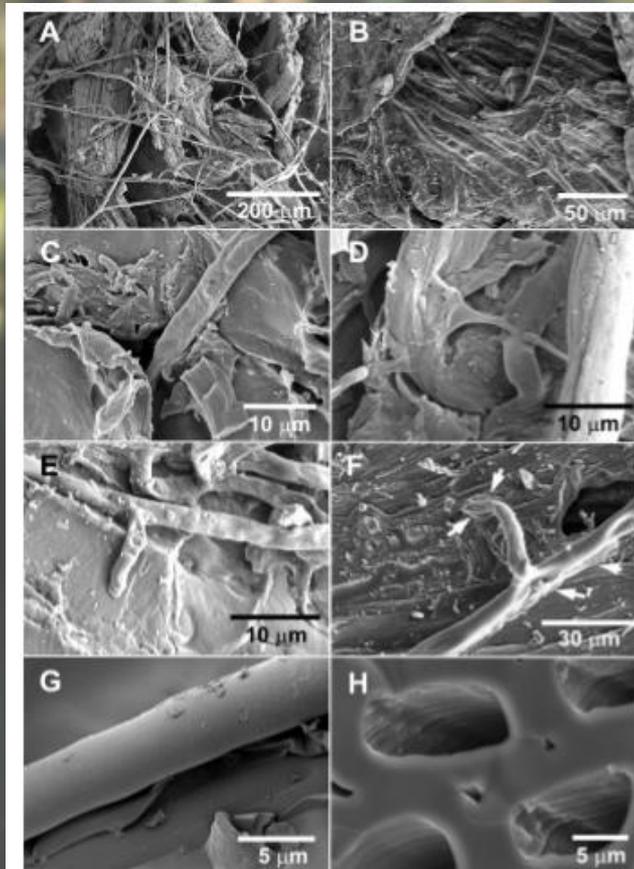


Fonte: Zhang et al. (2014)



Fonte: Farias, 2016 (dados não publicados)

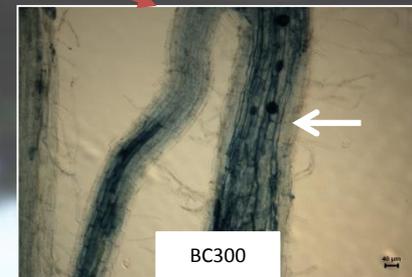
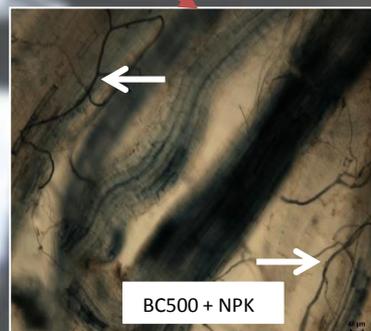
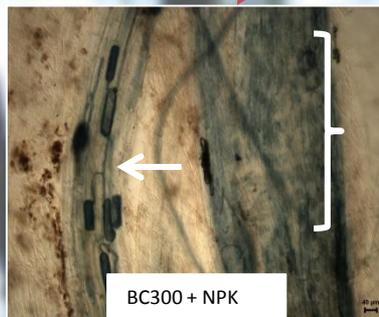
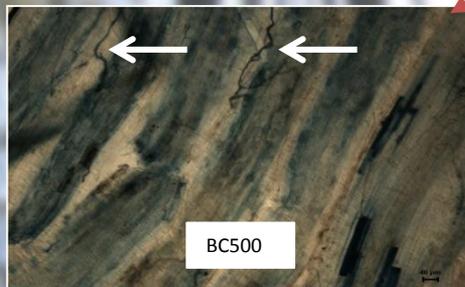
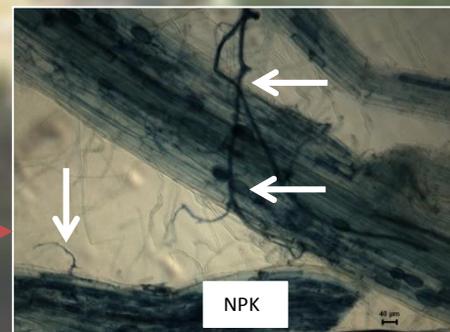
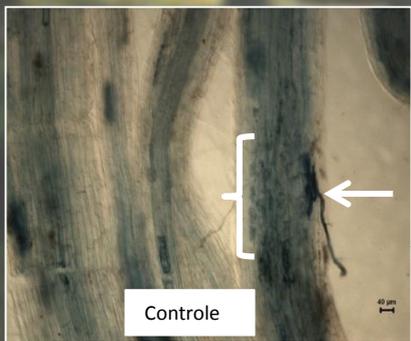
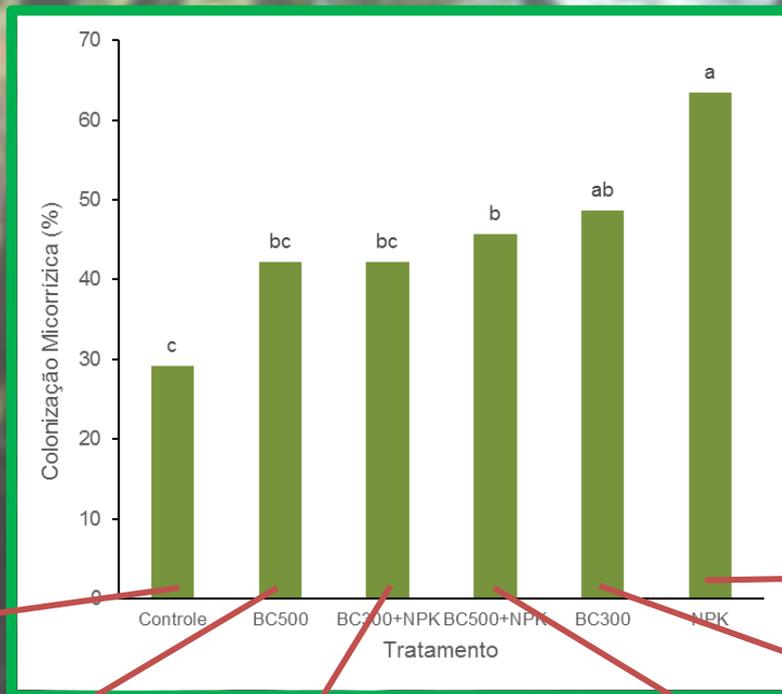
EFEITO DO BIOCHAR DE LODO DE ESGOTO NA MICROBIOTA DO SOLO – COLONIZAÇÃO MICORRÍZICA



A mycorrhizal fungus grows on biochar and captures phosphorus from its surfaces

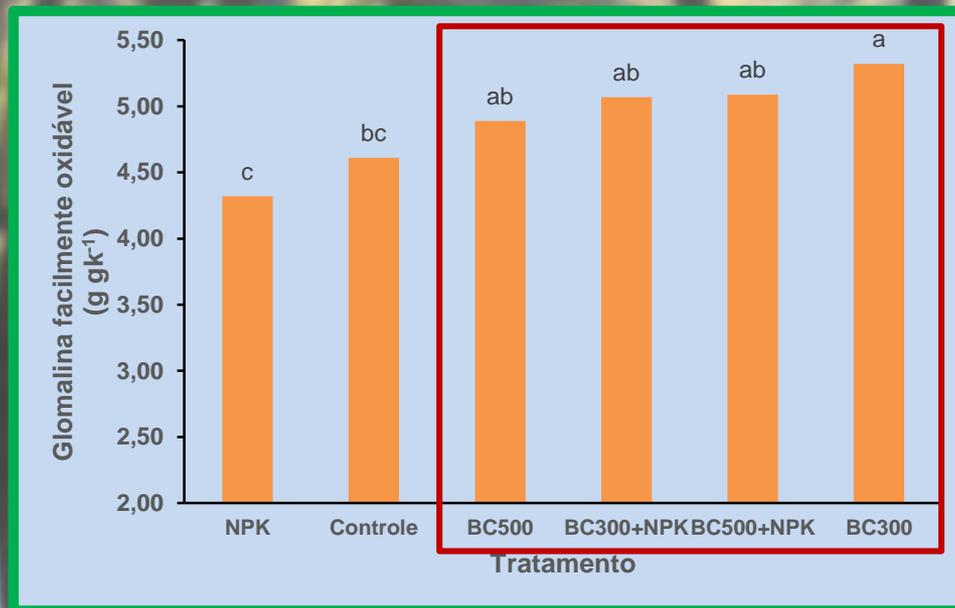
Edith C. Hammer^{a,b,c,*}, Zsuzsanna Balogh-Brunstad^{d,e,f}, Iver Jakobsen^a, Pål Axel Olsson^b, Susan L.S. Stipp^f, Matthias C. Rillig^c

EFEITO DO BIOCHAR DE LODO DE ESGOTO NA MICROBIOTA DO SOLO – COLONIZAÇÃO MICORRÍZICA

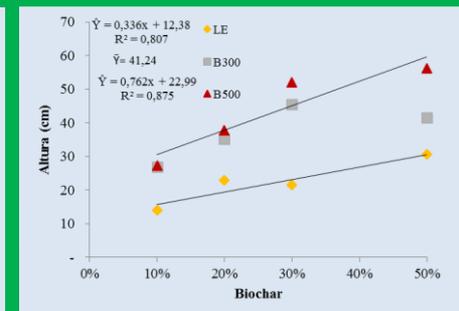
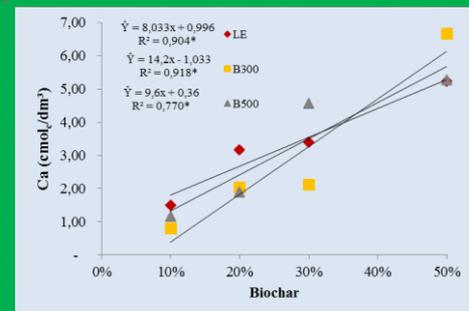
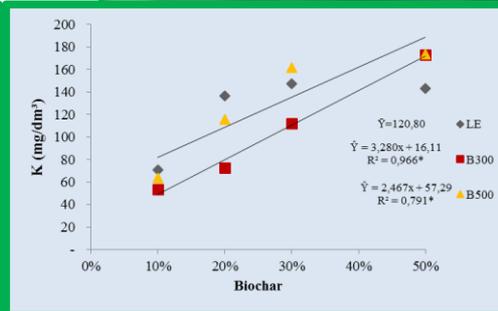
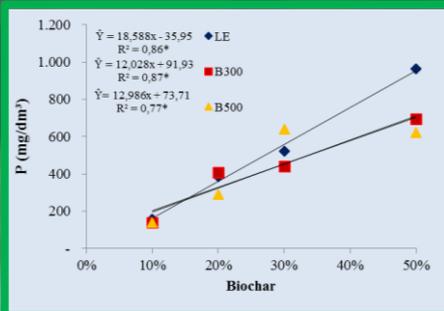
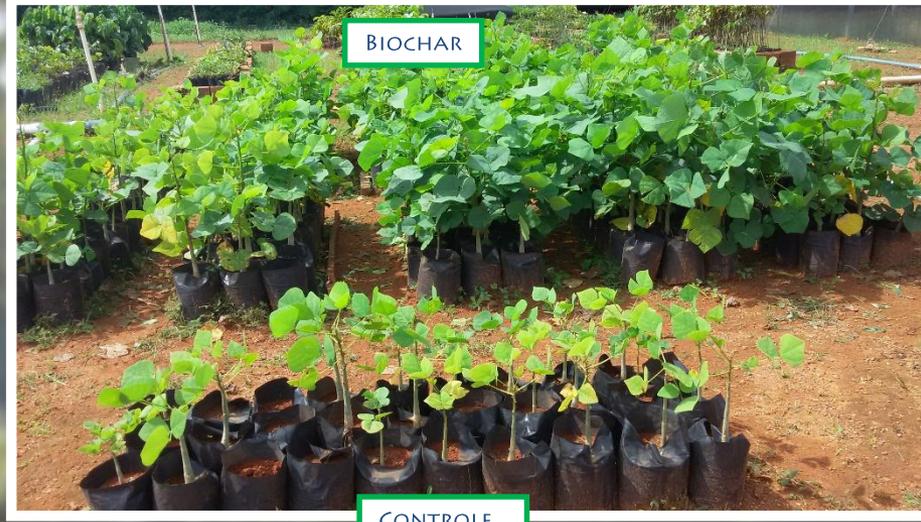
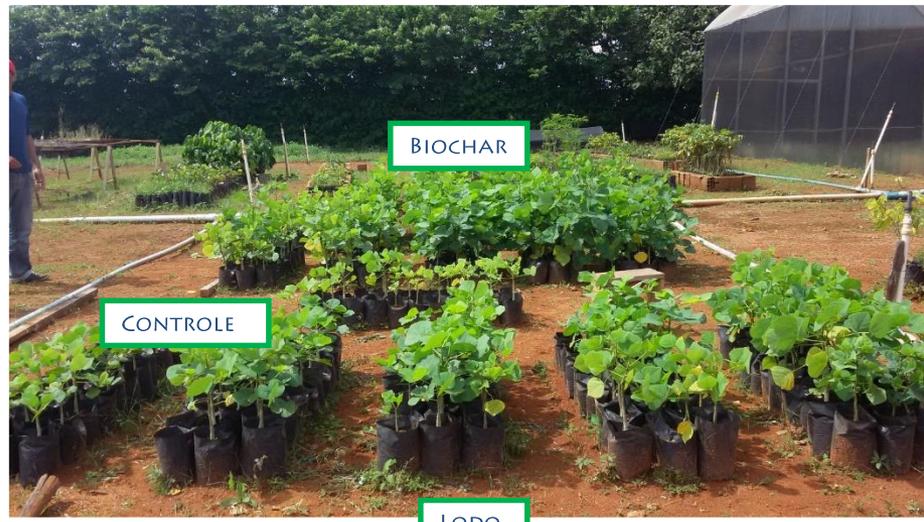


SETAS – HIFAS DE FMAS
CHAVES – PRESENÇA DE ARBÚSCULOS

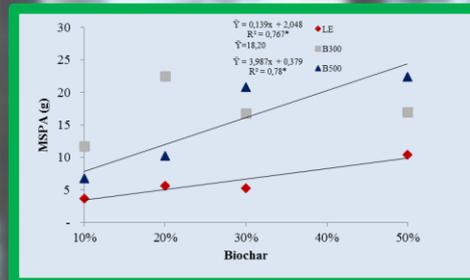
EFEITO DO BIOCHAR DE LODO DE ESGOTO NA GLOMALINA



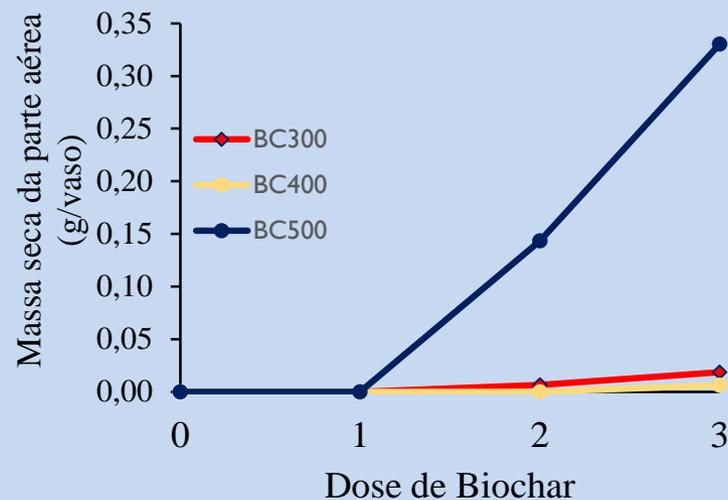
EFEITO DO BIOCHAR DE LODO DE ESGOTO NA QUALIDADE DE MUDAS ARBÓREAS (*Erythrina velutina* Willd.)



DOSES: 10%; 20%; 30%; 40%; 50% DE BIOCHAR (V/V)
CONTROLE: 100% TERRA



BIOCHAR DE LODO DE ESGOTO E SORÇÃO DE HERBICIDA (OXYFLUORFEN)



DOSES (M/M): 1: 1% BIOCHAR; 2: 5% BIOCHAR; 3: 10% BIOCHAR
PLANTA: PEPINO (*Cucumis sativum*)

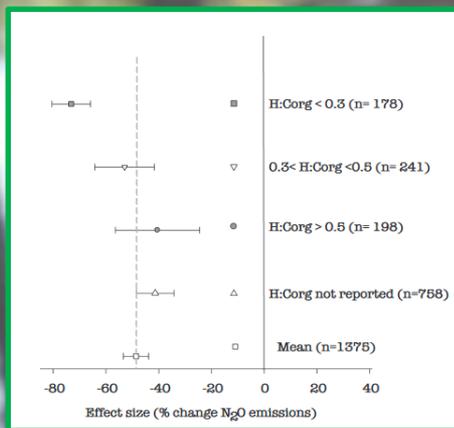
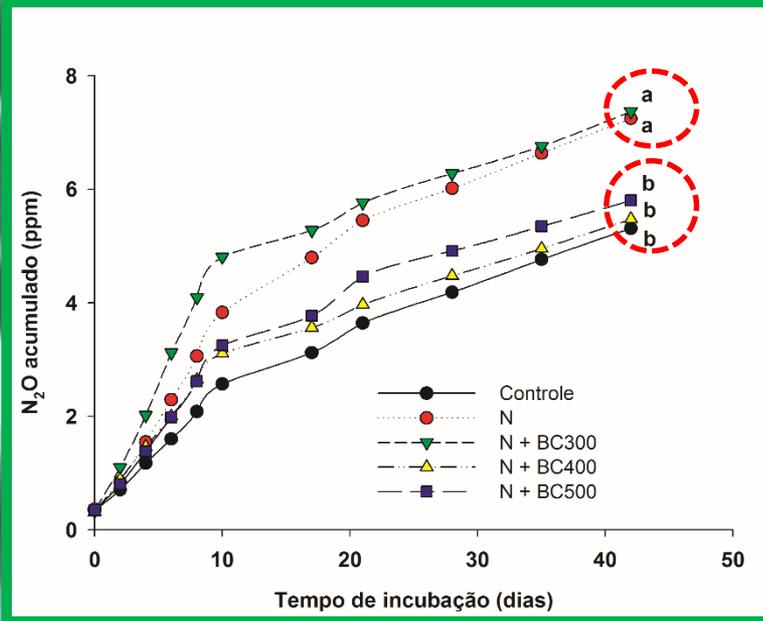
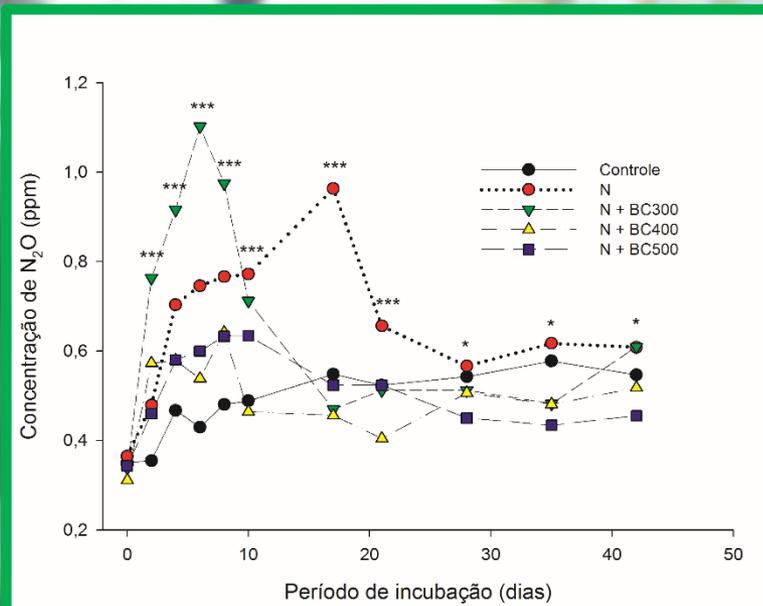
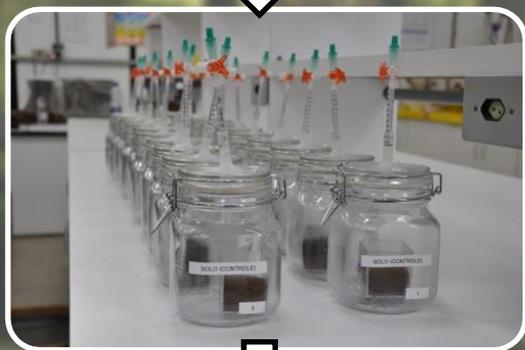


BIOCHAR E REDUÇÃO DA EMISSÃO DE N₂O



50 g de solo

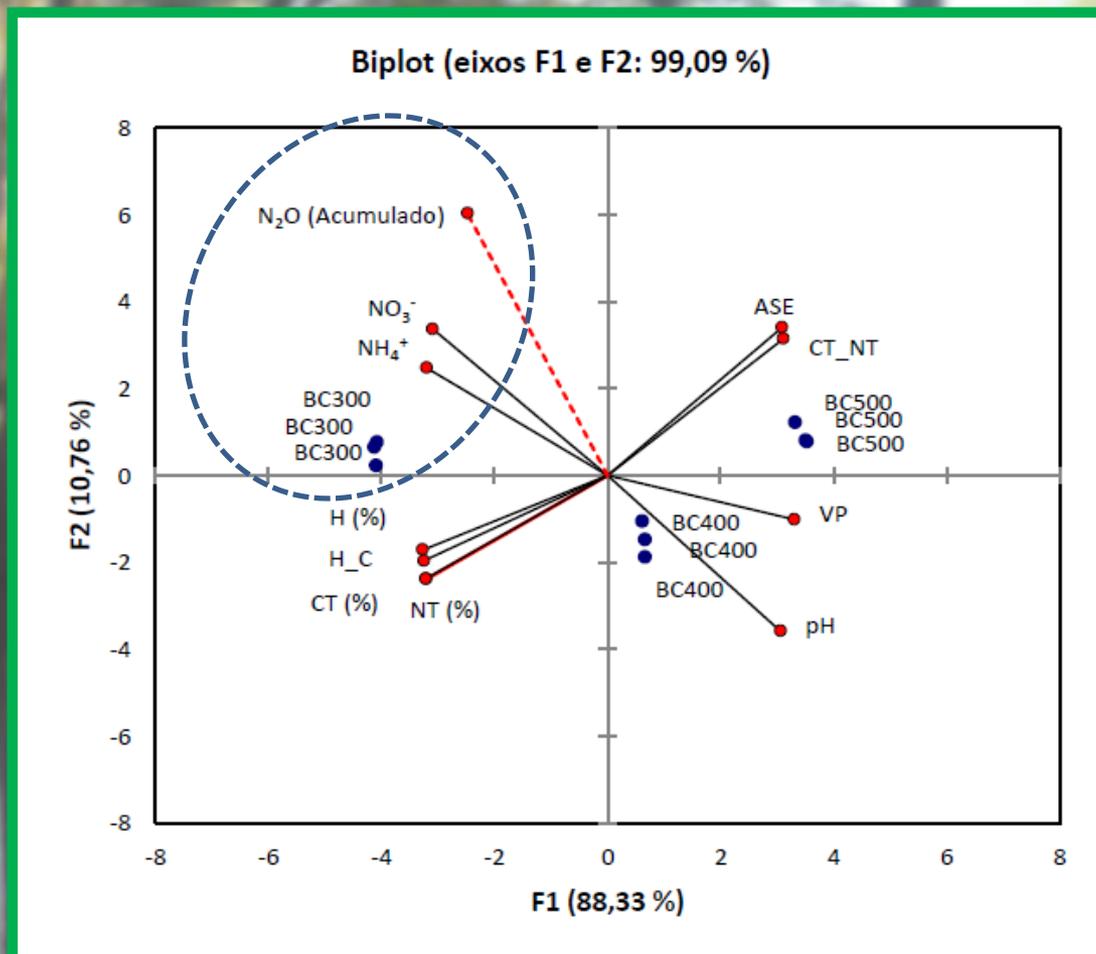
TRATAMENTOS	
1	Solo sem aplicação de biochar e de nitrogênio (controle).
2	Solo com aplicação de nitrogênio, sem biochar.
3	Solo com aplicação de nitrogênio e biochar 300 °C.
4	Solo com aplicação de nitrogênio e biochar 400 °C.
5	Solo com aplicação de nitrogênio e biochar 500 °C.



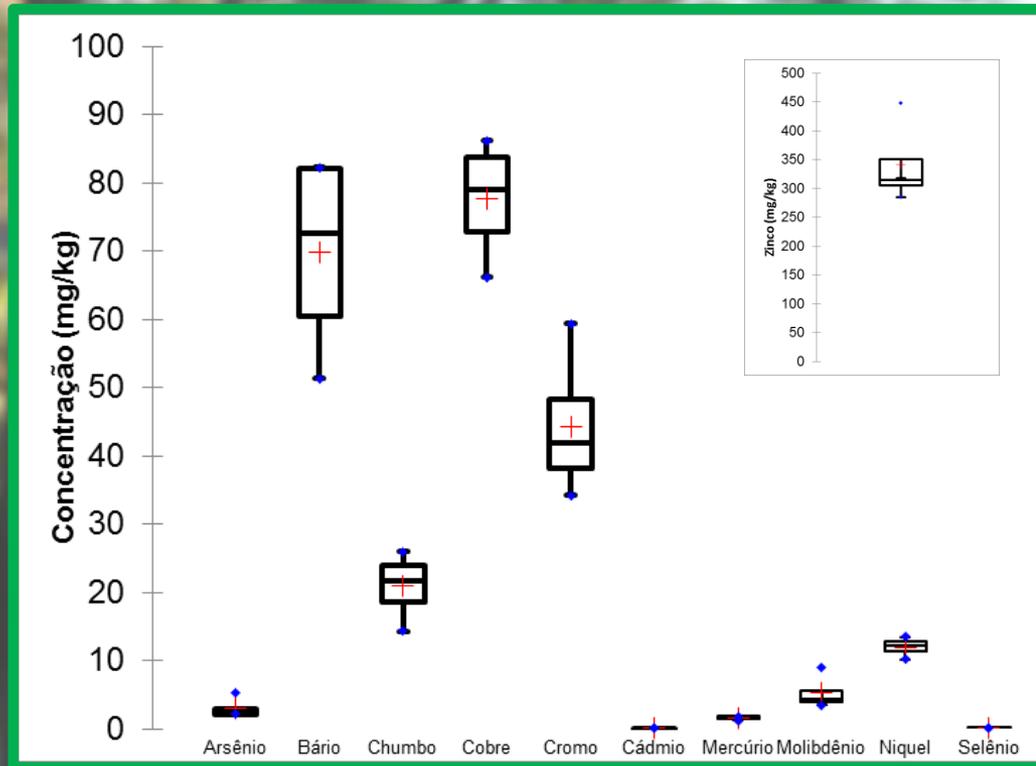
FONTE: ARAÚJO (2015)

Fonte: Cayuela et al (2015)

BIOCHAR E REDUÇÃO DA EMISSÃO DE N₂O

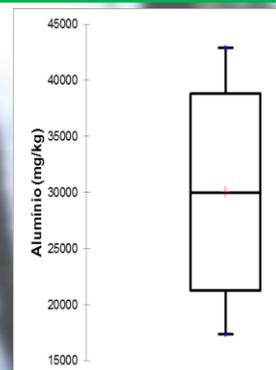


BIOCHAR DE LODO DE ESGOTO E BIOACUMULAÇÃO DE METAIS PESADOS



CONCENTRAÇÃO MÁXIMA PERMITIDA DE SUBSTÂNCIAS INORGÂNICAS EM LODO DE ESGOTO OU PRODUTOS DERIVADOS (CONAMA, 375)

Substâncias inorgânicas	Concentração (mg kg ⁻¹ , base seca)
Arsênio	41
Bário	1300
Cádmio	39
Chumbo	300
Cobre	1500
Cromo	1000
Mercúrio	17
Molibdênio	50
Níquel	420
Selênio	100
Zinco	2800

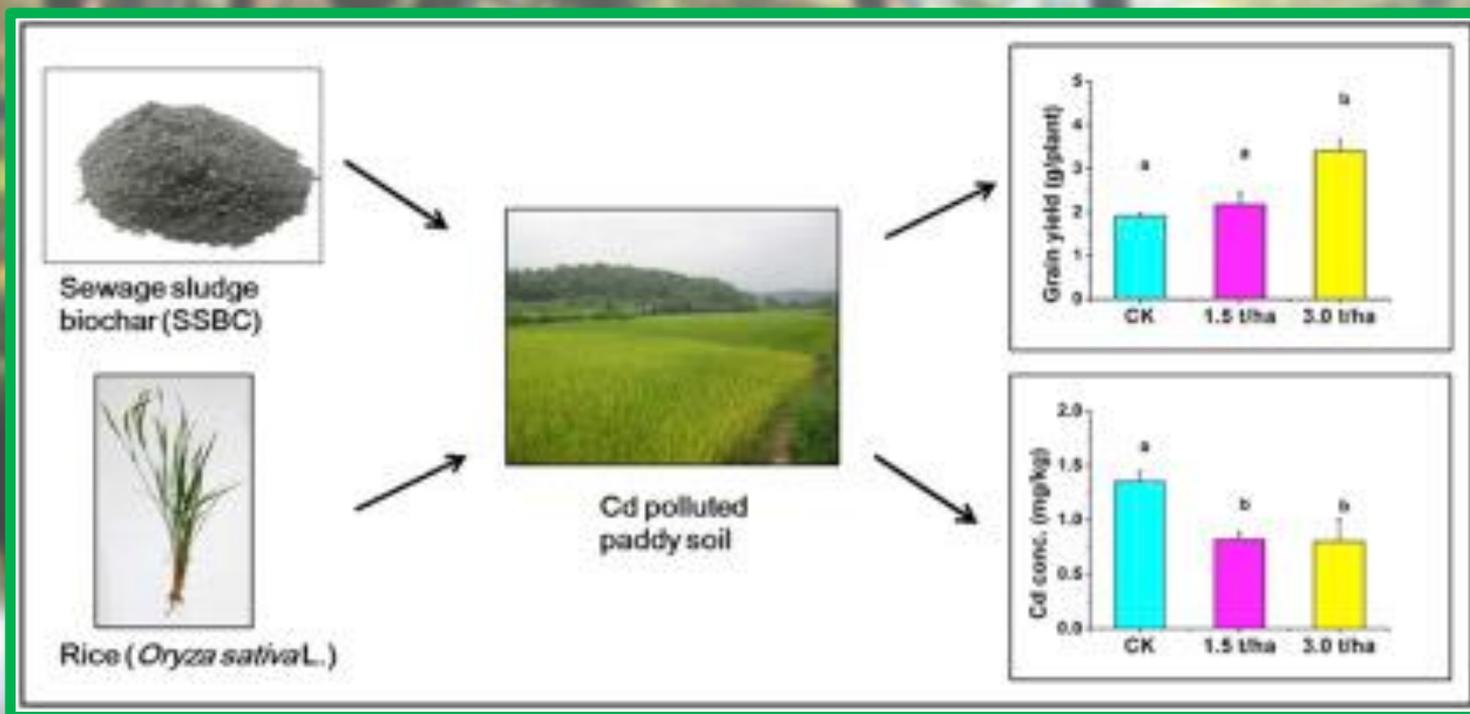


O caso do alumínio:
Teor de Al = 24.450 mg/kg

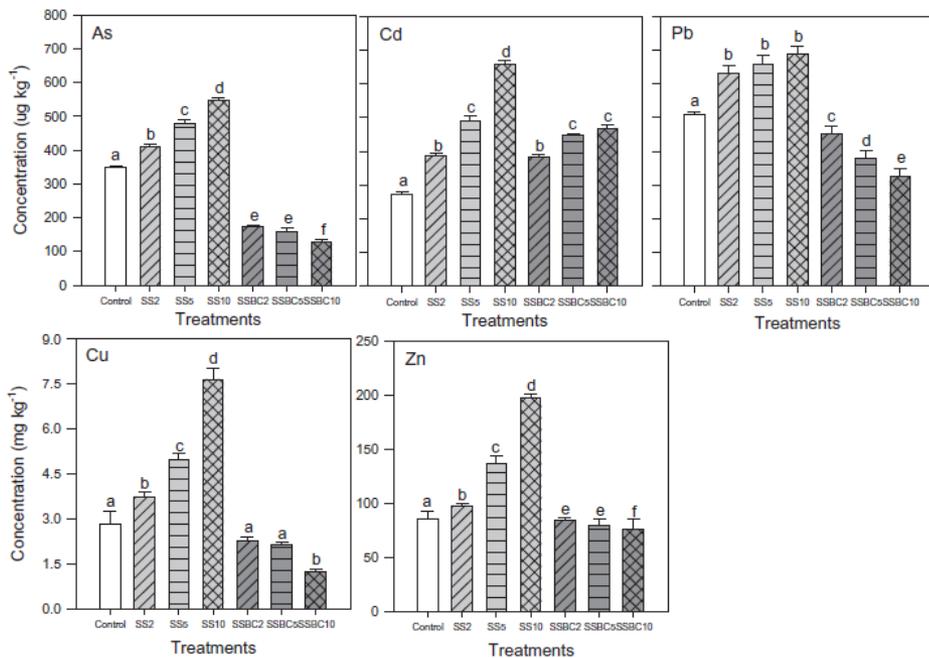
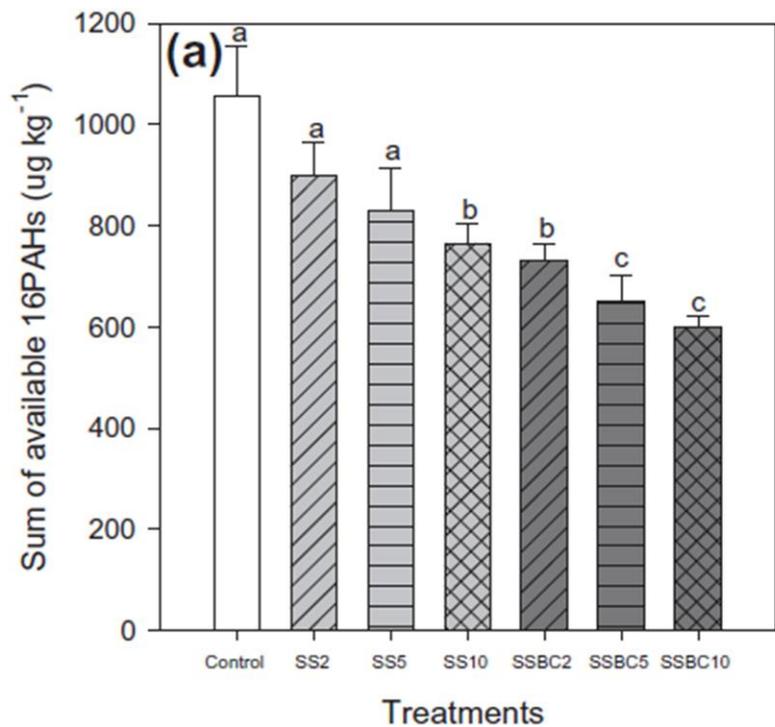
2 cmol_c/dm³

Atenção !!!

BIOCHAR DE LODO DE ESGOTO E BIOACUMULAÇÃO DE METAIS PESADOS



BIOCHAR E BIOACUMULAÇÃO DE MP E COMPOSTOS ORGÂNICOS TÓXICOS



POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

REMOÇÃO DE FÁRMACOS EM LODO DE ESGOTO PELO PROCESSO DE CARBONIZAÇÃO HIDROTÉRMICA

Physico-chemical characteristics of the 12 investigated pharmaceuticals. Decomposition temperature and log K_d are collected from literature, pK_a is collected from the online database drugbank.

	M	Sum formula	Decomposition temperature	pK_a	log K_d
	g/mol		°C		
Diclofenac	296.15	C ₁₄ H ₁₁ Cl ₂ NO ₂	280 (Tudja et al., 2001)	4.15	1.82 (Carballa et al., 2008)
Ibuprofen	206.28	C ₁₃ H ₁₈ O ₂	190 (Zayed et al., 2012)	4.9	1.58 (Carballa et al., 2008)
Phenazone	188.23	C ₁₁ H ₁₂ N ₂ O	300 (Fulias et al., 2013)	1.4	n.a.
Carbamazepine	236.27	C ₁₅ H ₁₂ N ₂ O	198 (Pinto et al., 2014)	n.a.	1.55 (Carballa et al., 2008)
Sulfamethoxazole	253.28	C ₁₀ H ₁₁ N ₃ O ₃ S	190 (Fernandes et al., 1999)	1.97	1.36 (Carballa et al., 2008)
Bezafibrate	361.82	C ₁₉ H ₂₀ ClNO ₄	250 (Berber et al., 2010)	3.83	1.5 (Narumiya et al., 2013)
Fenofibric acid	360.83	C ₂₀ H ₂₁ ClO ₄	n.a.	n.a.	n.a.
Metoprolol	267.36	C ₁₅ H ₂₅ NO ₃	n.a.	9.7	1.9 (Narumiya et al., 2013)
Propranolol	259.34	C ₁₆ H ₂₁ NO ₂	252 (Macedo et al., 2002)	9.42	2.52 (Martin et al., 2012)
Clarithromycin	747.95	C ₃₈ H ₆₉ NO ₁₃	245 (Adrjanowicz et al., 2012)	8.99	2.7 (Narumiya et al., 2013)
Roxithromycin	837.05	C ₄₁ H ₇₆ N ₂ O ₁₅	230 (Adrjanowicz et al., 2012)	9.08	2.6 (Narumiya et al., 2013)
Erythromycin	733.93	C ₃₇ H ₆₇ NO ₁₃	190 (Allen et al., 1978)	8.88	2.1 (Narumiya et al., 2013)

n.a. = not available.

	Measured concentration in spiked sewage sludge	Concentration after HTC	Removal during HTC
	µg/kg _{SDM}	µg/kg _{SDM}	%
Ibuprofen	350 ± 33	130 ± 15	63
Phenazone	210 ± 33	230 ± 6	No removal
Carbamazepine	560 ± 23	<20	>98
Bezafibrate	180 ± 8	<40	>89
Fenofibric acid	340 ± 23	<20	>97
Metoprolol	650 ± 96	400 ± 23	39
Propranolol	360 ± 120	70 ± 14	81
Clarithromycin	220 ± 55	<20	>95
Roxithromycin	190 ± 63	<10	>97
Erythromycin	180 ± 24	<10	>98

PERSPECTIVAS/DESAFIOS PARA USO DE BIOCHAR DE LODO DE ESGOTO

- ✓ INFORMAÇÕES DE EXPERIMENTOS DE LONGO PRAZO
- ✓ APROFUNDAR E AMPLIAR A CARACTERIZAÇÃO DE SUBSTÂNCIAS TÓXICAS/ METAIS
- ✓ CO-PRODUÇÃO DE BIOCHAR COM OUTRAS MATÉRIAS PRIMAS (REMINERALIZADORES E ORGANOMINERAIS)
- ✓ IDENTIFICAR OUTROS BENEFÍCIOS DO BIOCHAR (CONTROLE DE PRAGAS E DOENÇAS)
- ✓ AMPLIAR ESTUDOS SOBRE OS DEMAIS PRODUTOS GERADOS (GÁS E ÓLEO) NA PIRÓLISE
- ✓ ESTUDAR A EFICIÊNCIA ENERGÉTICA DO PROCESSO

AGRADECIMENTOS



LABORATÓRIO DE MOS



(Processo: 304617/2014-8)



(Processo: 0193.001058/2015)



Parceiros:

UnB
Embrapa
UENF



OBRIGADO PELA ATENÇÃO!



Pinterest
2016

CÍCERO CÉLIO DE FIGUEIREDO

LABORATÓRIO DE ESTUDOS DA MATÉRIA ORGÂNICA DO SOLO
FACULDADE DE AGRONOMIA E MEDICINA VETERINÁRIA
UNIVERSIDADE DE BRASÍLIA

cicerocf@unb.br

TEL. 6131077564