Tables and Figures

Table 1. Experimental treatment structure

Treatment name	Pyrolysis feedstock	Oxidation	Gas	Exposure time
ox wood biochar	wood	yes	none	none
ox wood biochar NH_3	wood	yes	$^{15}NH_3$	1 hour
ox wood biochar NH_3+CO_2	wood	yes	$^{15}NH_3 \rightarrow {}^{13}CO_2 \rightarrow {}^{14}NH_3 \rightarrow {}^{12}CO_2 \rightarrow {}^{15}NH_3 \rightarrow {}^{13}CO_2$	1 hour (each)
HSW biochar	HSW	none	none	none
HSW biochar CO_2+NH_3	HSW	none	$^{13}CO_2 \rightarrow {}^{15}NH_3$	1 hour (each)

Table 2. Rationale for urea-N additions (1x) in greenhouse trial based on the N uptake of wood biochar after exposure to CO_2+NH_3 relative to unexposed wood biochar. The final data for total N content in (unoxidized) wood biochar CO_2+NH_3 and wood biochar presented in Table 3 include additional measurements.

Count	Name	N (% w w^{-1})	ΔN wood biochar CO_2+NH_3 - wood biochar (% w w^{-1})	increase (g kg^{-1})	N added to wood biochar 1x (mg)
1	wood biochar CO_2+NH_3	2.16	0.98	9.75	35.10
2	wood biochar CO_2+NH_3	1.48			
3	wood biochar CO_2+NH_3	1.65			
4	wood biochar CO_2+NH_3	0.67			
5	wood biochar CO_2+NH_3	1.48			
6	wood biochar CO_2+NH_3	1.41			
	average	1.48			
average from previous work	wood biochar (control)	0.5			

Table 3. Total carbon and nitrogen and KCl-extractable ammonium (NH_4-N) and nitrate (NO_3-N) in amendments used for the greenhouse trial. Letters indicate significant differences between amendments ($p < 0.05$; n = 3).

Analysis	Unit	wood biochar	manure biochar	slurry	wood biochar NH_3+CO_2	manure biochar CO_2+NH_3	wood biochar +slurry	manure biochar +slurry	TH6 (peat+coir)
Nitrogen	% (w w^{-1})	0.75 ± 0.34 a	2.05 ± 0.05 a	2.75 ± 0.05 a	1.88 ± 1.48 a	2.11 ± 0.37 a	1.84 ± 0.15 a	2.21 ± 0.13 a	0.74 ± 0.23 a
Carbon	% (w w^{-1})	90.7 ± 0.35 a	44.3 ± 0.41 d	35.3 ± 0.15 e	88.2 ± 1.78 b	43.68 ± 0.75 d	73.7 ± 0.14 c	42.3 ± 0.32 d	25.67 ± 1.4 f
NH_4-N	mg kg^{-1}	4.38 ± 4.72 b	2.67 ± 3.09 b		3083 ± 143 a	3363 ± 335 a	15.5 ± 3.70 b	23.7 ± 22.2 b	606 ± 16.4 b
NO_3-N	mg kg^{-1}	0.81 ± 0.08 b	24.0 ± 2.10 b		4.67 ± 0.13 b	20.6 ± 2.72 b	0.49 ± 0.08 b	2.33 ± 1.16 b	635 ± 15.2 a

Table 4. Total N and C uptake in ox wood biochar and HSW biochar before and after exposure to NH_3 or NH_3+CO_2, calculated from sample AT% $^{15}N/^{14}N$ and AT% $^{13}C/^{12}C$ ratios, accounting for the change in sample mass (**Error! Reference source not found.**). Letters represent greater than 95% probability of means differences, $p < 0.05$.

Sample	Mass change (%w w^{-1})	Total N (%w w^{-1})	AT% $^{15}N/^{14}N$	$\delta^{15}N$ vs. At. Air	$^{14}N+^{15}N$ uptake (mg g^{-1})	Total C (%w w^{-1})	AT% $^{13}C/^{12}C$	$\delta^{13}C$ vs. VPDB	$^{12}C+^{13}C$ uptake (mg g^{-1})
HSW biochar CO_2+NH_3	2.36 ± 0.65	5.20 ± 0.15	1.04 ± 0.09	1860.46 ± 249.19	3.97 ± 0.54 (**b**)	45.88 ± 0.73	1.11 ± 0.00	-18.71 ± 1.11	4.04 ± 0.73 (**b**)
HSW biochar		4.57 ± 0.04	0.37 ± 0.00	9.16 ± 0.05		44.04 ± 0.66	1.11 ± 0.00	-22.93 ± 0.13	
ox wood biochar NH_3+CO_2	14.7 ± 0.30	3.53 ± 0.70	6.57 ± 0.93	18227.6 ± 2928.23	46.43 ± 15.72 (**a**)	67.35 ± 5.02	1.10 ± 0.00	-25.7 ± 0.01	21.93 ± 11.30 (**a**)
ox wood biochar NH_3	4.29 ± 0.72	3.59 ± 0.66	7.38 ± 1.90	20847.98 ± 5987.03	28.40 ± 7.78 (**ab**)	71.48 ± 0.24	1.10 ± 0.00	-26.01 ± 0.04	n/a
ox wood biochar		0.20 ± 0.01	0.38 ± 0.00	22.81 ± 1.46		74.13 ± 1.73	1.10 ± 0.00	-25.36 ± 0.07	

n/a not applicable

Table 5. The FTIR wavenumber range assignments depicted in Figure 2A and associated functional groups (56).

Peak number	Highlighted frequency (cm^{-1})	Frequency range (cm^{-1})	Functional group
1	2154	2200-2100	Alkynes C≡C
		2600-2200	Nitriles C≡N
		2240-2220	Aromatic cyanide
		2150-1990	Isothiocyanate -NCS
2	1709	1725-1700	Carboxylic acid
		1725-1705	Ketone
3	1570	1630-1575	Open chain azo -N=N-
		1615-1580	C=C-C aromatic ring stretch
		1650-1550	Primary or secondary amine NH bend
4	1435	1440-1390	Ammonium ion NH_4^+
5	1362	1350-1280	Aromatic secondary amine, CN stretch
		1360-1310	Aromatic tertiary amine CN stretch
6	1215	1200	Phenol C-OH stretch
7	1034	1055–1020	Silicone Si-O-Si
		1050-990	Aliphatic phosphates
		1090-1020	**Primary amine C-N stretch**

Table 6. The relative proportion of bond forms containing C, N, and O associated with the BE range of curve centers shown in Figure 2B. Deconvolution relied on standard compounds as well as online and published literature (58,59,60) shown in Table S2 and Table S3.

Core level	Bond	BE range (eV)	Peak	HSW biochar CO_2+NH_3	HSW biochar	ox wood biochar CO_2+NH_3	ox wood biochar NH_3	ox wood biochar
				area %	area (%)	area (%)	area (%)	area (%)
C1s	C-C, C=C (i)	283.0-284.0	7	0.00	0.00	0.00	0.00	30.02
C1s	C-C, C=C	284.0-285.0	6	48.31	53.29	56.48	40.39	38.17
C1s	C-N	285.0-286.0	5	31.15	29.77	21.49	34.01	0.00
C1s	C-OH	286.0-287.0	4	9.35	9.74	10.11	10.62	14.00
C1s	R-C=O (R aromatic)	287.0-287.5	--	0.00	0.00	0.00	0.00	8.79
C1s	R-C=O	287.5-288.0	3	2.81	4.28	5.29	6.85	0.00
C1s	(C=O)-OH	288.5-288.8	2	0.00	0.00	5.01	6.76	6.68
C1s	N-C=O	289.0-290.5	1	8.37	2.92	1.63	1.36	2.33
N1s	pyridinic N	398.0-398.9	15,14	26.4	44.14	27.32	23.33	0.00
N1s	C-NH_2	399.0-399.5	13	28.02	0.00	0.00	4.23	0.00
N1s	C-O--NH_4^+	399.5-400.0	12	28.96	0.00	55.89	60.32	0.00
N1s	N=C-(C=O)	400.0-400.5	11	0.00	48.27	0.00	0.00	0.00
N1s	N-C-(C=O)	400.5-400.9	10	14.87	0.00	0.00	0.00	100
N1s	NH_4^+	401.9-403.0	9,8	1.75	7.59	16.79	12.12	0.00
O1s	R-C-OH	531.0-531.3	20	75.42	69.8	0.00	0.00	0.00
O1s	C=O	531.3-532.0	19	0.00	0.00	55.74	59.38	51.98
O1s	C-O	532.0-533.3	18	19.7	26.49	44.26	40.62	48.02
O1s	H_2O, OH	533.5-536.0	16,17	4.88	3.71	0.00	0.00	0.00

Table 7. The binding energies (BE) and full-width at half-maximum values (FWHM) of deconvoluted curves of ox wood biochar and HSW biochar samples before and after exposure to NH_3 and CO_2, measured with XPS, shown in Figure 2B.

Core level	Bond	BE range (eV)	Peak	HSW biochar CO_2+NH_3		HSW biochar		ox wood biochar CO_2+NH_3		ox wood biochar NH_3		ox wood biochar	
				BE (eV)	FWHM	E (eV)	FWHM	BE (eV)	FWHM	BE (eV)	FWHM	BE (eV)	FWHM
C1s	C-C, C=C (i)	283.0-284.0	7	--	--	--	--	--	--	--	--	283.76	1.54
C1s	C-C, C=C	284.0-285.0	6	284.31	1.36	284.34	1.46	284.43	1.45	284.19	1.62	284.83	1.54
C1s	C-N	285.0-286.0	5	285.07	1.36	285.39	1.46	285.32	1.45	285.00	1.62	--	--
C1s	C-OH	286.0-287.0	4	286.12	1.36	286.55	1.46	286.4	1.45	286.35	1.62	286.03	1.54
C1s	R-C=O (R aromatic)	287.0-287.5	--	--	--	--	--	--	1.45	--	--	287.46	1.54
C1s	R-C=O	287.5-288.0	3	287.73	1.36	287.93	1.46	287.69	1.45	287.66	1.62	--	--
C1s	(C=O)-OH	288.5-288.8	2	--	--	--	--	288.76	1.45	288.69	1.62	288.80	1.54
C1s	N-C=O	289.0-290.5	1	289.37	1.36	289.47	1.46	290.02	1.45	290.07	1.62	290.14	1.54
N1s	pyridinic N	398.0-389.9	15,14	398.00	1.20	398.35	1.85	398.75	1.86	398.63	1.97	--	--
N1s	C-NH_2	399.0-399.5	13	398.94	1.20	--	--	--	--	399.29	1.97	--	--
N1s	C-O--NH_4^+	399.5-400.0	12	399.9	1.20	--	--	399.96	1.86	399.71	1.97	--	--
N1s	N=C-(C=O)	400.0-400.5	11	--	--	400.08	1.85	--	--	--	--	--	--
N1s	N-C-(C=O)	400.5-400.9	10	400.67	1.20	--	--	--	--	--	--	400.77	4.93
N1s	NH_4^+	401.0-403.0	9,8	401.89	1.20	401.88	1.85	401.32	1.86	401.23	1.97	--	--
O1s	R-C-OH	531.0-531.3	20	531.23	1.87	531.15	1.99	--	--	--	--	--	--
O1s	C=O	531.3-532.0	19	--	--	--	--	531.58	2.17	531.38	2.25	531.56	2.59
O1s	C-O	532.0-533.3	18	532.54	1.87	532.61	1.99	533.23	2.17	533.08	2.25	533.10	2.59
O1s	H_2O, OH	533.5-536.0	16,17	535.70	1.87	534.86	1.99	--	--	--	--	--	--

Table 8. Total nutrients measured in acid-digested ($HClO_4$+HNO_3) amendments used for the greenhouse trial. Letters indicate significant differences between amendments ($p < 0.05$; n = 3).

Analysis	Unit	wood biochar	manure biochar	slurry
Al	g kg^{-1}	0.38 + 0.02 b	4.03 + 1.57 a	0.35 + 0.28 b
Ca	g kg^{-1}	5.25 + 0.04 b	158 + 12.4 a	49.5 + 42.0 a
K	g kg^{-1}	5.54 + 0.26 a	12.8 + 1.85 a	37.5 + 32.4 a
Mg	g kg^{-1}	0.75 + 0.01 b	15.9 + 0.12 a	7.66 + 6.56 ab
Na	g kg^{-1}	0.47 + 0.01 a	3.92 + 0.51 a	8.78 + 7.55 a
P	g kg^{-1}	0.55 + 0.02 b	11.9 + 0.90 a	7.17 + 6.16 ab
S	g kg^{-1}	0.09 + 0.00 a	2.30 + 0.20 a	3.53 + 3.03 a
Micros (B+Cu+Fe+Mn+Zn)	g kg^{-1}	0.80 + 0.03 b	3.14 + 0.19 a	0.99 + 0.75 b
H. metals (Cd, Pb)	mg kg^{-1}	3.04 + 0.33 b	15.3 + 3.64 a	2.34 + 1.08 b

Table 9. Plant-available nutrients in amendments, extracted with Mehlich-III. Letters indicate significant differences between amendments ($p < 0.05$; n = 3).

Analysis	Unit	wood biochar	manure biochar	wood biochar NH_3+CO_2	manure biochar CO_2+NH_3	wood biochar+slurry	manure biochar+ slurry
Al	mg kg^{-1}	130 ± 4.58 a	0.82 ± 0.53 d	83.5 ± 3.95 b	0.00 ± 0.14 d	17.4 ± 3.62 c	10.8 ± 1.62 c
Ca	g kg^{-1}	3.46 ± 0.06 e	25.9 ± 0.03 a	2.53 ± 0.08 f	21.8 ± 0.16 c	11.9 ± 0.36 d	23.8 ± 0.33 b
K	g kg^{-1}	7.00 ± 0.05 d	9.87 ± 0.14 c	6.47 ± 0.07 d	10.4 ± 0.20 c	18.7 ± 0.82 a	13.1 ± 0.31 b
Mg	g kg^{-1}	0.58 ± 0.02 d	3.00 ± 0.01 a	0.48 ± 0.00 d	2.50 ± 0.03 c	2.46 ± 0.09 c	2.71 ± 0.04 b
Na	g kg^{-1}	0.81 ± 0.06 b	2.40 ± 0.01 a	0.68 ± 0.04 c	2.41 ± 0.00 a	2.36 ± 0.00 a	2.39 ± 0.00 a
P	g kg^{-1}	0.32 ± 0.00 d	1.08 ± 0.01 b	0.23 ± 0.00 e	0.91 ± 0.00 c	1.71 ± 0.06 a	0.17 ± 0.03 a
S	mg kg^{-1}	62.1 ± 1.66 c	302 ± 3.45 a	55.1 ± 0.81 c	290 ± 3.39 a	214 ± 8.84 b	303 ± 8.00 a
Micros (B,Cu,Fe, Mn,Zn)	mg kg^{-1}	358 ± 8.78 a	146 ± 0.61 c	260 ± 8.72 b	122 ± 1.21 d	264 ± 0.54 b	143 ± 2.82 c
H. metals (Cd,Pb)	mg kg^{-1}	9.83 ± 3.9 a	0.84 ± 0.02 b	0.14 ± 0.32 b	0.75 ± 0.01 b	1.42 ± 0.16 b	0.61 ± 0.06 b

Table 10. pH of potting mix and amendments after 40 days, percent increase in dry shoot and root biomass relative to unamended plants (0x), total N shoot and root uptake, and percent increase in total shoot and root N uptake relative to unamended plants. Letters indicate significant differences between amendments within plant and biomass type ($p < 0.05$; n = 4).

plant	amend.	pH after 40 days	shoot relative biomass increase	Total shoot N uptake	shoot relative N uptake increase	root relative biomass increase	Total root N uptake	root relative N uptake increase
			% (w w^{-1})	(g)	% (w w^{-1})	% (w w^{-1})	(g)	% (w w^{-1})
marigold	0x fert	6.11 ± 0.07 d	0.00 ± 0.00 bc	2.77 ± 0.39 b	0.00 ± 0.00 c	0.00 ± 0.00 ab	0.80 ± 0.05 ab	0.00 ± 0.00 ab
marigold	0.25x fert	6.15 ± 0.18 d	19.4 ± 17.9 ab	3.09 ± 0.85 b	11.9 ± 30.77 bc	22.5 ± 21.78 ab	0.94 ± 0.13 ab	18.1 ± 16.8 ab
marigold	0.5x fert	6.33 ± 0.55 cd	31.9 ± 20.6 ab	2.99 ± 0.59 b	8.03 ± 21.5 bc	17.6 ± 20.1 ab	0.91 ± 0.08 ab	14.0 ± 10.2 ab
marigold	1x fert	6.17 ± 0.02 d	33.3 ± 25.6 ab	4.12 ± 0.49 ab	49.1 ± 17.6 ab	18.54 ± 15.3 ab	1.04 ± 0.07 ab	30.3 ± 8.72 ab
marigold	1.5x fert	6.36 ± 0.3 cd	40.6 ± 19.4 ab	5.18 ± 0.69 a	87.4 ± 25.1 a	5.17 ± 9.75 ab	0.95 ± 0.17 ab	19.5 ± 21.7 ab
marigold	manure biochar	7.08 ± 0.12 a	-2.89 ± 6.31 bc	2.43 ± 0.34 b	-12.0 ± 12.4 c	-7.60 ± 31.1 b	0.72 ± 0.19 b	-10.1 ± 23.3 b
marigold	manure biochar+slurry	7.07 ± 0.13 a	-1.76 ± 20.9 bc	2.55 ± 0.54 b	-7.91 ± 19.6 c	17.9 ± 17.6 ab	0.86 ± 0.17 ab	8.22 ± 21.0 ab
marigold	manure biochar CO_2+NH_3	6.83 ± 0.46 abc	-37.7 ± 41.9 c	2.55 ± 1.76 b	17.2 ± 20.1 bc	-4.76 ± 20.1 ab	0.87 ± 0.13 ab	9.51 ± 16.5 ab
marigold	manure biochar+1x	7.05 ± 0.03 ab	19.6 ± 0.00 abc	4.50 ± 0.00 ab	62.74 ± 0.12 ab	-0.30 ± 0.00 ab	0.73 ± 0.00 ab	-8.54 ± 0.00 ab
marigold	wood biochar	6.30 ± 0.14 cd	31.8 ± 6.61 ab	2.46 ± 0.32 b	-10.9 ± 11.7 c	14.0 ± 30.3 ab	0.78 ± 0.15 ab	-2.68 ± 18.5 ab
marigold	wood biochar+slurry	6.47 ± 0.12 bcd	17.1 ± 14.7 ab	2.54 ± 0.30 b	-8.00 ± 10.8 c	-1.52 ± 18.8 ab	0.78 ± 0.17 ab	-2.82 ± 21.3 ab
marigold	wood biochar NH_3+CO_2	6.32 ± 0.11 cd	35.7 ± 16.6 ab	3.76 ± 0.93 ab	35.9 ± 33.5 bc	17.02 ± 16.5 ab	0.89 ± 0.03 ab	11.1 ± 3.42 ab
marigold	wood biochar+1x	6.25 ± 0.05 cd	55.8 ± 8.46 a	4.24 ± 0.24 ab	53.2 ± 8.66 ab	45.6 ± 20.3 a	1.10 ± 0.23 a	37.2 ± 29.1 a
radish	0x fert	6.48 ± 0.12 cd	0.00 ± 0.00 b	1.10 ± 0.35 bc	0.00 ± 0.00 bcd	0.00 ± 0.00 c	1.86 ± 0.42 d	0.00 ± 0.00 d
radish	0.25x fert	6.5 ± 0.16 cd	36.3 ± 39.7 ab	1.88 ± 0.59 abc	70.9 ± 53.6 abcd	21.8 ± 20.3 bc	2.12 ± 0.43 cd	14.2 ± 23.3 cd
radish	0.5x fert	6.34 ± 0.14 d	14.9 ± 16.1 ab	1.65 ± 0.53 abc	49.4 ± 48.5 abcd	38.6 ± 12.4 abc	2.63 ± 0.26 abcd	41.4 ± 14.2 abcd
radish	1x fert	6.35 ± 0.15 d	40.1 ± 22.6 ab	2.14 ± 0.53 ab	94.4 ± 48.2 ab	32.0 ± 26.4 abc	3.16 ± 0.24 ab	70.2 ± 13.2 ab
radish	1.5x fert	6.37 ± 0.14 d	73.79 ± 44.61 a	2.69 ± 0.85 a	144 ± 77.1 a	31.71 ± 39.0 abc	2.91 ± 0.72 abc	56.4 ± 38.6 abc
radish	manure biochar	7.22 ± 0.1 ab	-4.53 ± 19.0 b	0.96 ± 0.17 c	-12.5 ± 15.0 cd	25.9 ± 31.4 bc	2.05 ± 0.41 cd	10.6 ± 21.9 cd
radish	manure biochar+slurry	7.31 ± 0.12 a	30.1 ± 16.6 ab	1.18 ± 0.25 bc	7.49 ± 22.8 bcd	26.41 ± 13.8 abc	1.98 ± 0.20 cd	6.29 ± 10.71 cd

radish	manure biochar CO_2+NH_3	7.25 ± 0.13 a	27.2 ± 26.6 ab	2.04 ± 0.31 abc	84.8 ± 27.9 abc	51.3 ± 15.8 abc	3.49 ± 0.63 a	87.9 ± 33.9 a
radish	manure biochar+1x	7.02 ± 0.56 ab	21.0 ± 15.4 ab	1.38 ± 0.13 bc	25.7 ± 11.7 bcd	77.6 ± 8.80 a	3.29 ± 0.18 a	76.9 ± 9.47 a
radish	wood biochar	6.74 ± 0.04 bcd	9.06 ± 14.9 b	0.92 ± 0.13 c	-16.3 ± 12.0 d	35.4 ± 11.9 abc	2.25 ± 0.41 bcd	20.8 ± 22.0 bcd
radish	wood biochar+slurry	6.90 ± 0.16 abc	18.1 ± 33.9 ab	1.05 ± 0.31 bc	-4.76 ± 28.2 cd	22.2 ± 10.2 bc	2.21 ± 0.17 bcd	18.8 ± 9.39 cd
radish	wood biochar NH_3+CO_2	6.45 ± 0.06 cd	59.2 ± 33.7 ab	1.90 ± 0.64 abc	72.9 ± 58.1 abcd	65.2 ± 19.0 ab	3.15 ± 0.25 ab	69.3 ± 13.3 ab
radish	wood biochar+1x	6.48 ± 0.14 cd	49.2 ± 14.7 ab	1.61 ± 0.34 abc	46.6 ± 30.6 abcd	67.8 ± 26.5 ab	3.24 ± 0.33 a	74.1 ± 17.7 a
tomato	0x fert	6.35 ± 0.13 c	0.00 ± 0.00 bcd	3.42 ± 0.36 def	0.00 ± 0.00 def	0.00 ± 0.00 bc	0.55 ± 0.09 b	0.00 ± 0.00 b
tomato	0.25x fert	6.28 ± 0.14 c	10.7 ± 18.7 abcd	3.93 ± 0.44 cde	15.2 ± 13.0 cde	19.05 ± 20.6 bc	0.70 ± 0.07 ab	26.8 ± 12.6 ab
tomato	0.5x fert	6.30 ± 0.04 c	20.1 ± 8.93 abcd	4.63 ± 0.28 bc	35.6 ± 8.09 bc	15.9 ± 27.5 bc	0.67 ± 0.11 b	20.6 ± 20.7 b
tomato	1x fert	6.15 ± 0.14 c	8.87 ± 22.1 abcd	5.29 ± 0.39 b	55.0 ± 11.6 b	10.6 ± 23.0 bc	0.78 ± 0.06 ab	40.4 ± 10.2 ab
tomato	1.5x fert	6.25 ± 0.11 c	-8.96 ± 16.9 d	6.57 ± 1.11 a	92.4 ± 32.4 a	-28.6 ± 26.7 c	0.58 ± 0.17 b	5.12 ± 31.0 b
tomato	manure biochar	7.46 ± 0.16 a	-6.82 ± 8.39 cd	2.86 ± 0.23 f	-16.4 ± 6.61 f	10.5 ± 9.7 bc	0.57 ± 0.07 b	2.90 ± 11.9 b
tomato	manure biochar+slurry	7.35 ± 0.43 a	0.58 ± 11.8 bcd	3.01 ± 0.11 ef	-11.9 ± 3.22 ef	19.6 ± 18.2 bc	0.69 ± 0.13 ab	23.8 ± 23.6 b
tomato	manure biochar CO_2+NH_3	7.41 ± 0.24 a	31.1 ± 6.98 ab	4.45 ± 0.41 bcd	30.2 ± 12.1 bcd	18.0 ± 5.57 bc	0.72 ± 0.06 ab	29.7 ± 10.9 ab
tomato	manure biochar+1x	7.35 ± 0.04 a	24.0 ± 12.4 abc	4.27 ± 0.32 bcd	24.9 ± 9.37 bcd	32.8 ± 24.1 ab	0.71 ± 0.15 ab	28.2 ± 26.4 ab
tomato	wood biochar	6.53 ± 0.19 c	1.48 ± 7.67 bcd	2.96 ± 0.37 ef	-13.3 ± 10.9 ef	24.9 ± 17.5 ab	0.60 ± 0.05 b	7.74 ± 9.36 b
tomato	wood biochar+slurry	7.03 ± 0.18 ab	5.59 ± 11.3 abcd	3.42 ± 0.13 def	0.02 ± 3.74 def	17.5 ± 33.6 bc	0.60 ± 0.15 b	8.24 ± 28.0 b
tomato	wood biochar NH_3+CO_2	6.62 ± 0.13 bc	21.3 ± 8.44 abcd	4.45 ± 0.11 bcd	30.2 ± 3.17 bcd	35.5 ± 13.8 ab	0.73 ± 0.08 ab	32.1 ± 14.8 ab
tomato	wood biochar+1x	6.51 ± 0.15 c	33.4 ± 13.7 a	4.78 ± 0.36 bc	39.8 ± 10.5 bc	69.3 ± 6.69 a	0.95 ± 0.08 a	70.7 ± 15.3 a

Figures

Figure captions

Figure 1. Thermodynamics and kinetics of CO_2 and NH_3 adsorption onto ox wood biochar and HSW biochar. (A) Enthalpic profile showing the heat of adsorption before and after exposure to CO_2 followed by NH_3. Shaded regions represent measurement uncertainty. (B) Thermograms depicting the weight change of the first replicate of HSW biochar and ox wood biochar exposed to CO_2 (orange) followed by NH_3 (blue), separated by an argon purge (gray). (C) The first replicate of gravimetrically-measured CO_2 and NH_3 adsorption at three sequential exposure intervals onto ox wood biochar (indicated in gray, orange, and blue lines for intervals 1, 2, and 3, respectively) overlaid with modeled adsorption curves using the Avrami fractional order model (indicated by solid, narrow dashed, and wide dashed lines for intervals 1, 2, and 3, respectively). (D) The first replicate of gravimetrically-measured CO_2 and NH_3 adsorption onto HSW biochar (blue line) overlaid with modeled adsorption curves using the Avrami fractional order model (black line). Avrami model parameters are presented in Table S1. Measured and modeled gravimetric CO_2 and NH_3 adsorption is presented in Figure S3 in the supplementary material.

Figure 2. (A) Normalized ATR-FTIR absorbance spectra of powdered samples. Difference spectra (diff.) were normalized relative to controls, HSW biochar or ox wood biochar. Numbered peak features are explained in Table 5. (B) Normalized intensity of counts within C1s, N1s, and O1s regions of experimental samples, measured with XPS. Points show measured spectra while the black line is the modeled spectra after deconvolution. Features marked with dotted lines and numbers and relative areas of peaks used for deconvolution are provided in Table S3. Numbered peak features are explained in Tables 6 and 7.

Figure 3. Figure 1. Increase in shoot and root biomass of plants grown with urea fertilizer (green points), manure biochar (brown points) or wood biochar (gray points) amendments relative to unamended plants (0x). Letters indicate significant differences between amendments within plant and biomass type ($p < 0.05$; n = 4).

Figure 4. Total nitrogen uptake in shoot and root biomass of plants grown with urea fertilizer, manure biochar or wood biochar amendments or no amendments (0x). Letters indicate significant differences between amendments within plant and biomass type ($p < 0.05$; n = 4).

Figure 5. The increase in nitrogen uptake in root and shoot biomass of plants amended with fertilizer (green points), manure biochar (brown points) or wood biochar (gray points) relative to unamended plants (0x). Letters indicate significant differences between amendments within plant and biomass type ($p < 0.05$; n = 4).

Figures

Figure 1

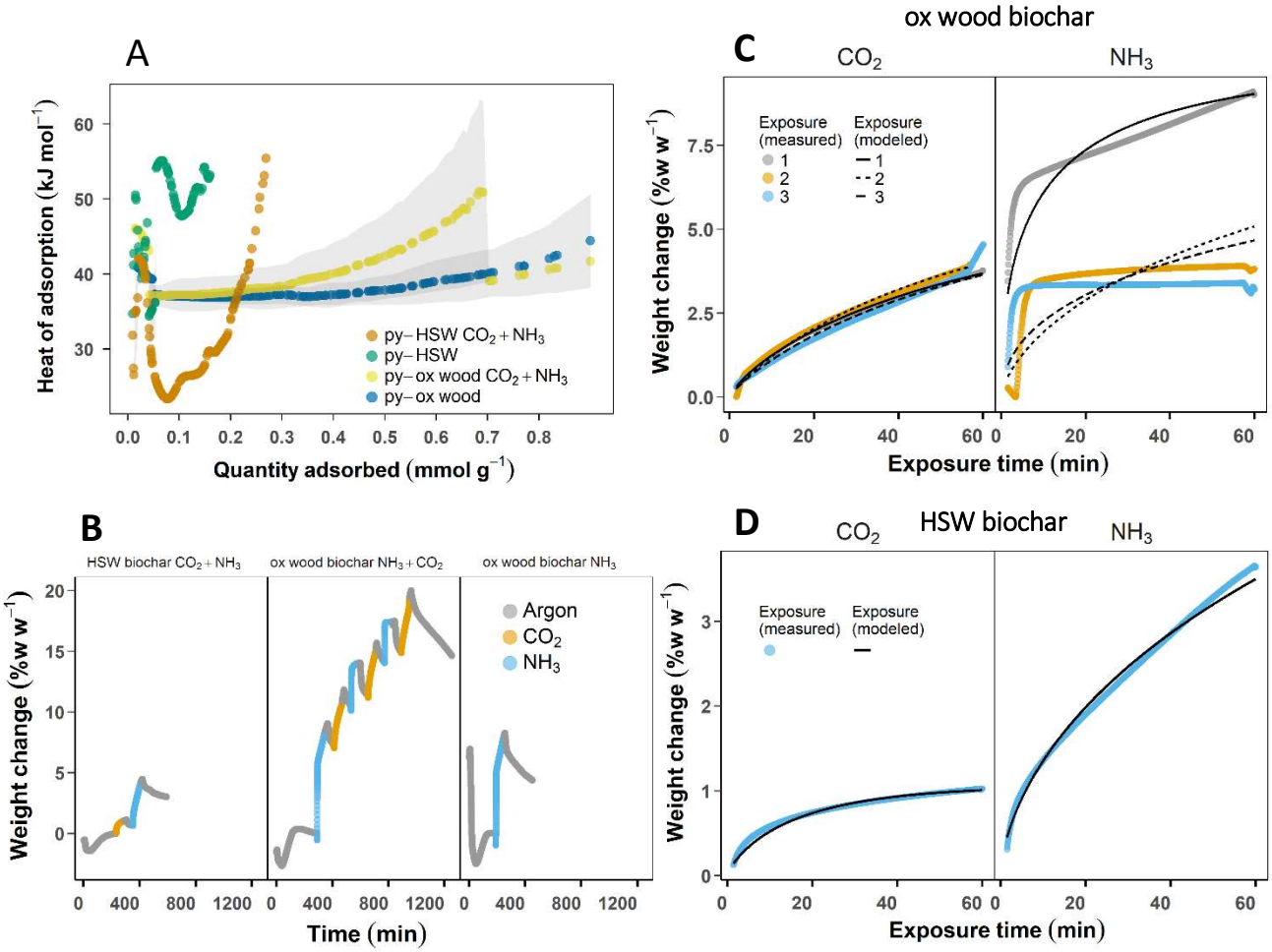


Figure 2

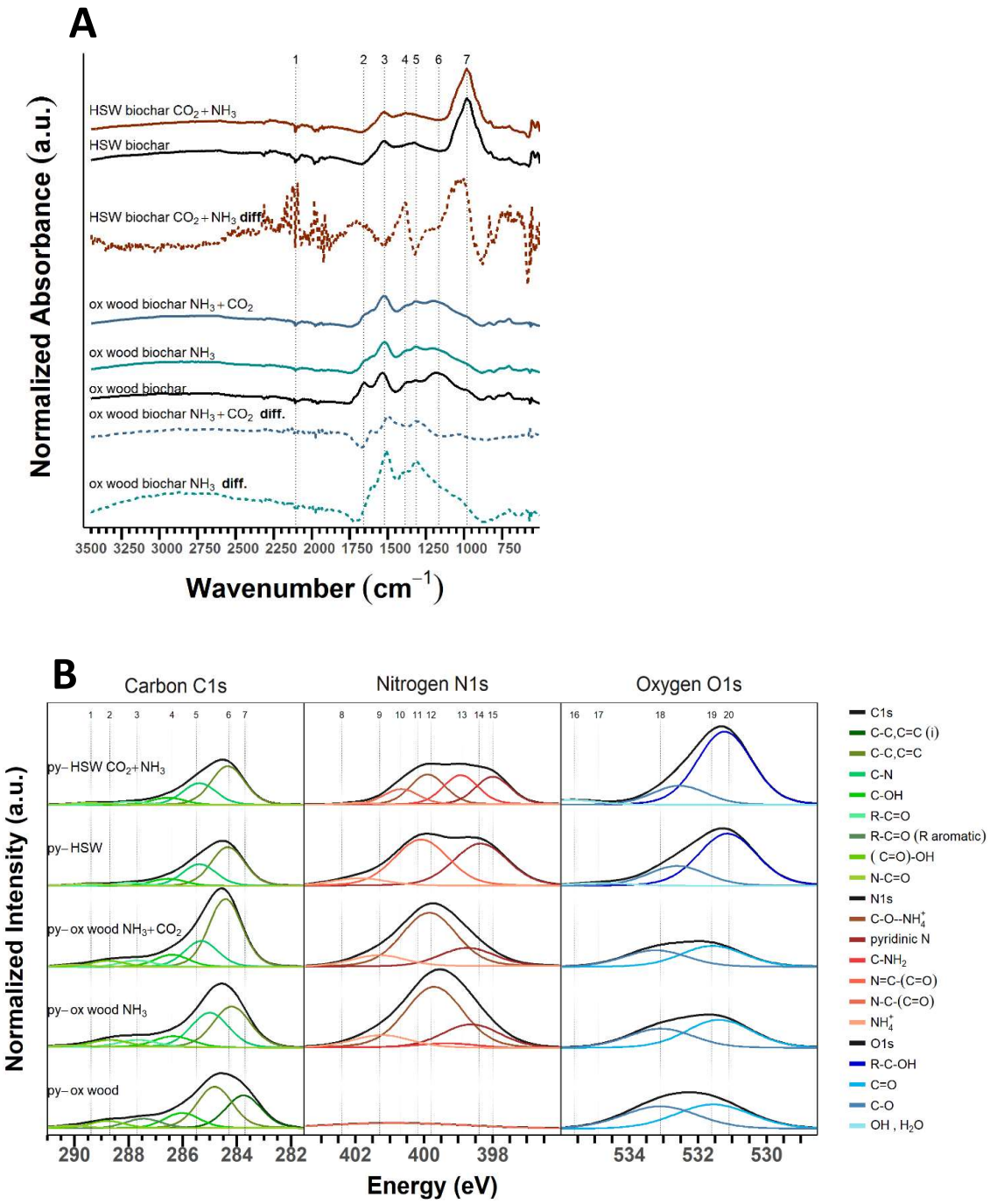

A
Normalized Absorbance (a.u.)
HSW biochar CO_2+NH_3
HSW biochar
HSW biochar CO_2+NH_3 diff.
ox wood biochar NH_3+CO_2
ox wood biochar NH_3
ox wood biochar
ox wood biochar NH_3+CO_2 diff.
ox wood biochar NH_3 diff.
3500 3250 3000 2750 2500 2250 2000 1750 1500 1250 1000 750
Wavenumber (cm^{-1})
B
Carbon C1s
Nitrogen N1s
Oxygen O1s
Normalized Intensity (a.u.)
py–HSW CO_2+NH_3
py–HSW
py–ox wood NH_3+CO_2
py–ox wood NH_3
py–ox wood
290 288 286 284 282 402 400 398 534 532 530
Energy (eV)
C1s
C-C,C=C (i)
C-C,C=C
C-N
C-OH
R-C=O
R-C=O (R aromatic)
(C=O)-OH
N-C=O
N1s
C-O--NH_4^+
pyridinic N
C-NH_2
N=C-(C=O)
N-C-(C=O)
NH_4^+
O1s
R-C-OH
C=O
C-O
OH , H_2O

Figure 3

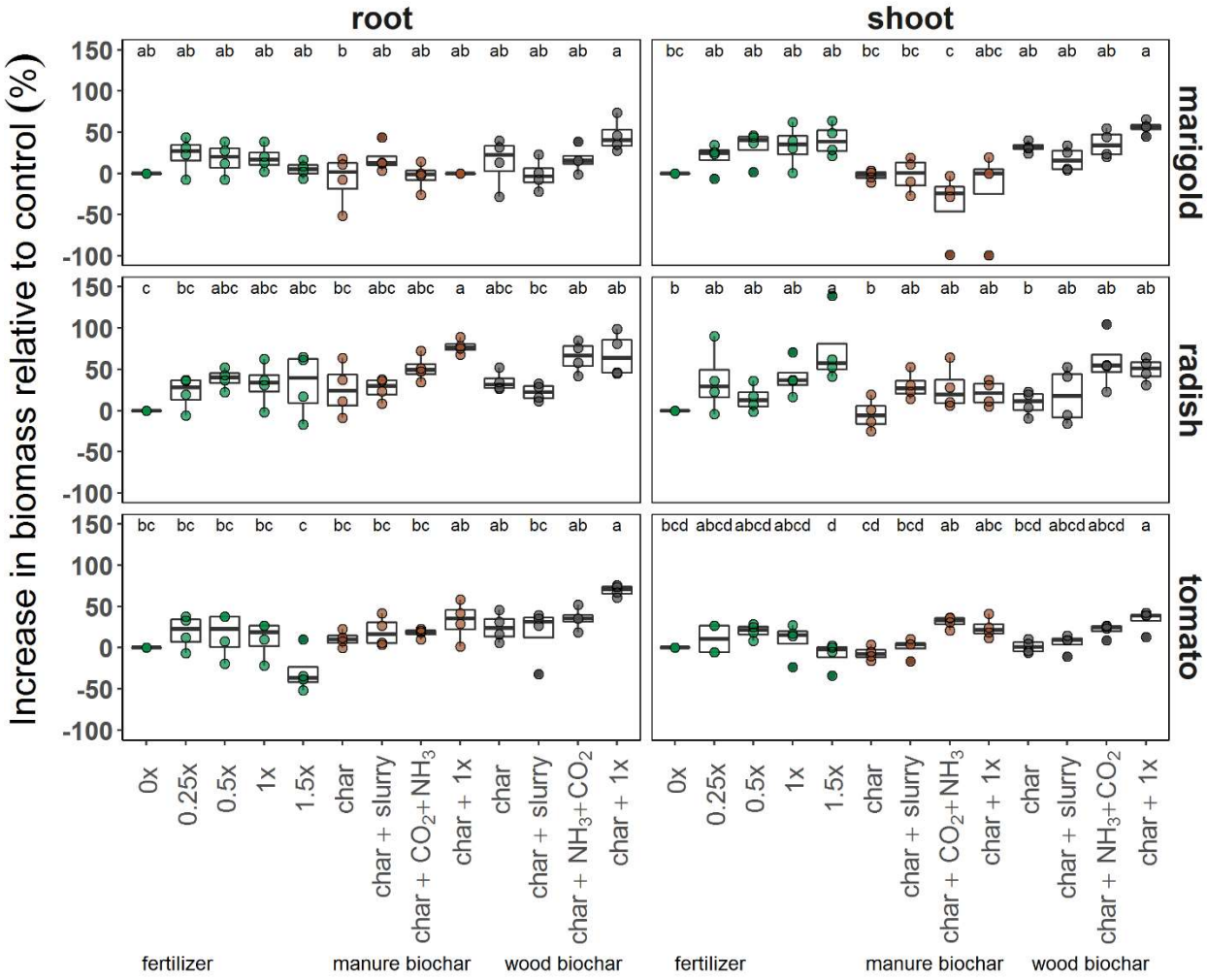

root
shoot
Increase in biomass relative to control (%)
marigold
radish
tomato
0x
0.25x
0.5x
1x
1.5x
char
char + slurry
char + CO2+NH3
char + 1x
char
char + slurry
char + NH3+CO2
char + 1x
fertilizer
manure biochar
wood biochar

Figure 4

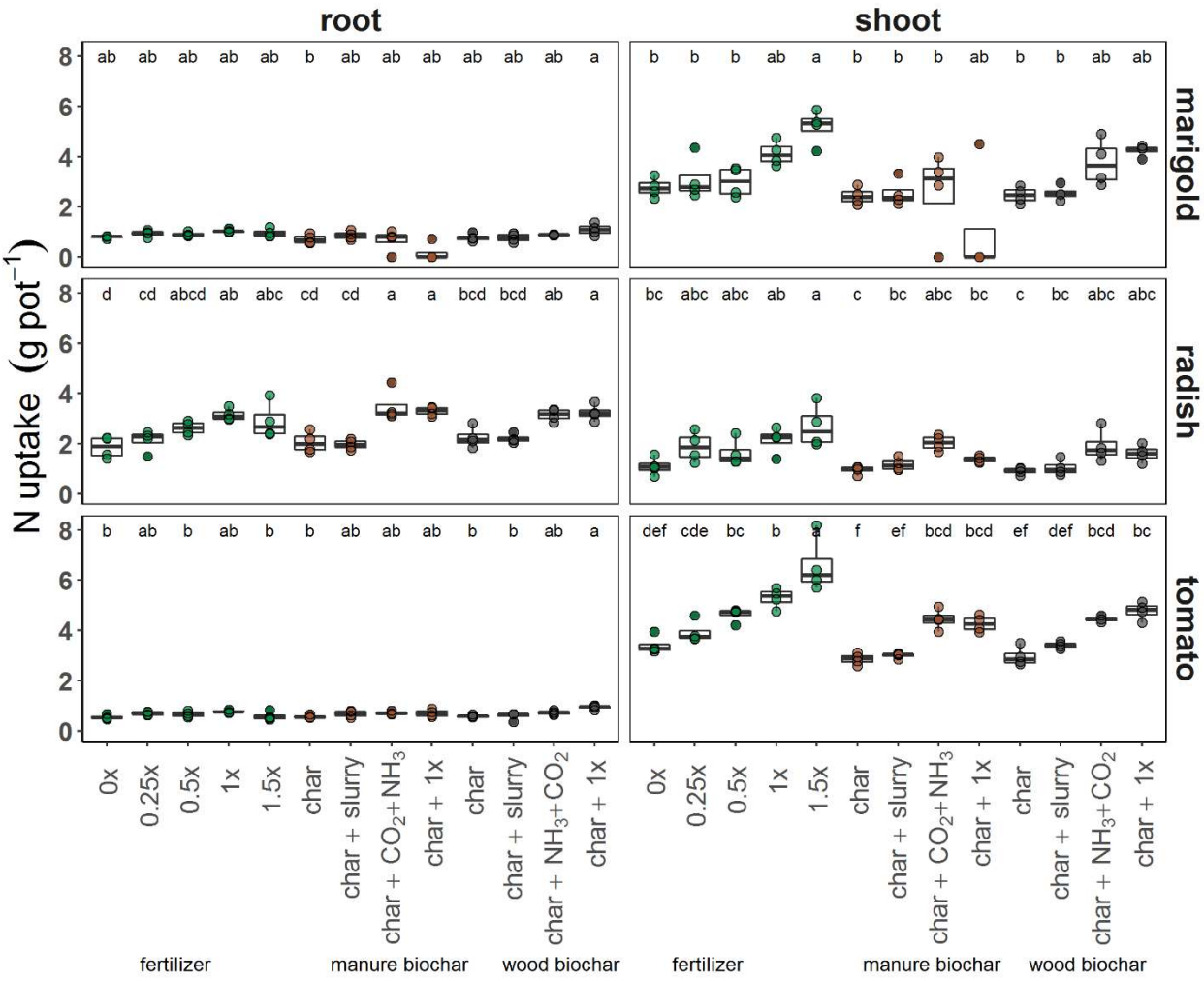
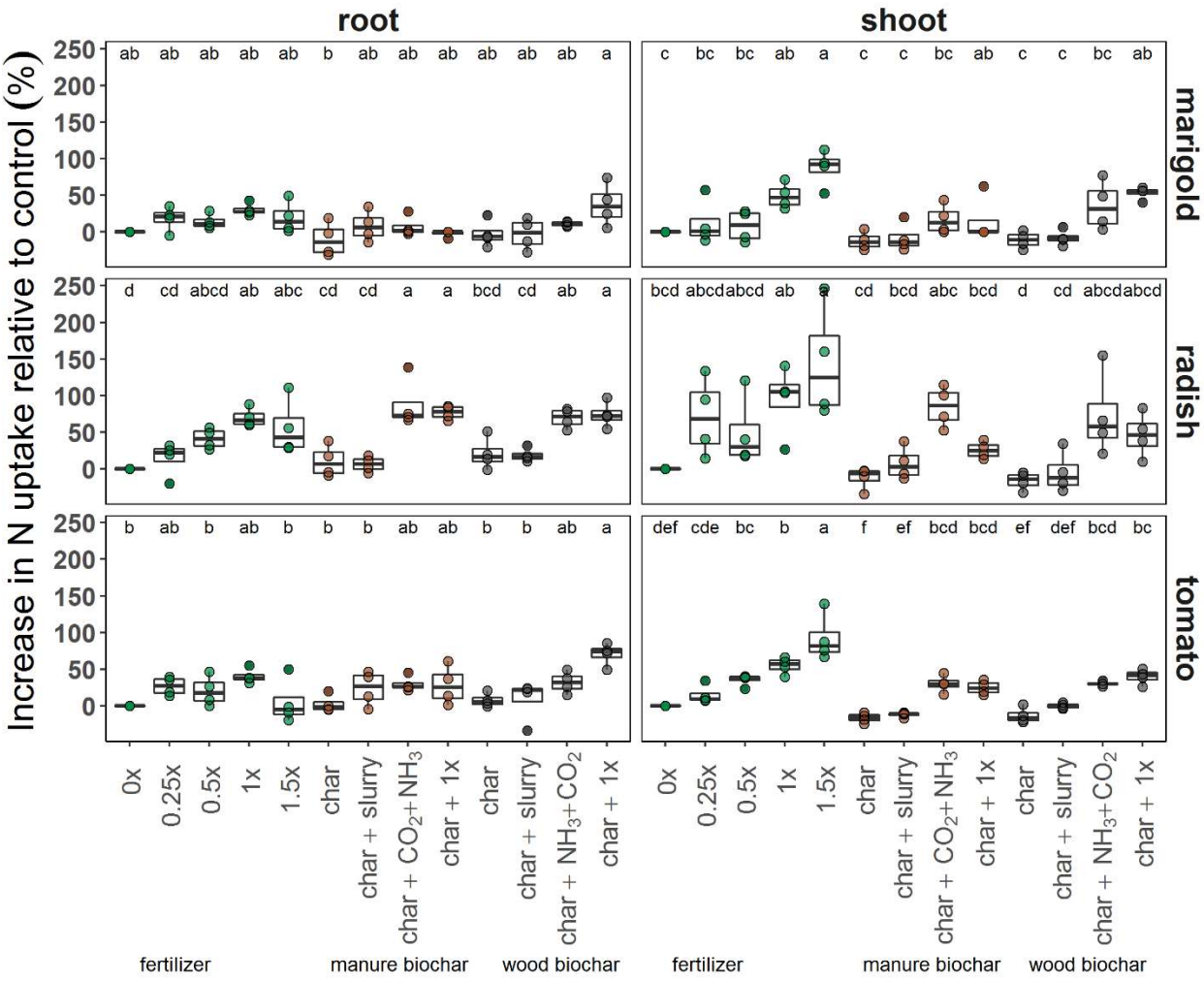

root
shoot
marigold
radish
tomato
N uptake (g pot^{-1})
0x
0.25x
0.5x
1x
1.5x
char
char + slurry
char + CO_2+NH_3
char + 1x
char + NH_3+CO_2
fertilizer
manure biochar
wood biochar

Figure 5


root
shoot
marigold
radish
tomato
Increase in N uptake relative to control (%)
0x
0.25x
0.5x
1x
1.5x
char
char + slurry
char + CO2+NH3
char + 1x
char
char + slurry
char + NH3+CO2
char + 1x
fertilizer
manure biochar
wood biochar