

Supplementary Materials

Title: Effects of Rice Husk Biochar on Carbon Release and Nutrient Availability in Three Cultivation Age of Greenhouse Soils

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Supplemental Figure

Materials and Methods

Scanning electron microscopy (SEM) observations of RHB used powdered samples that were placed on aluminum stubs using carbon tape, and electron micrographs were obtained using FEI Inspect S (Thermo Fisher Scientific Inc., Waltham, Massachusetts, USA). Chemical functional groups were determined by Fourier transform infrared spectra (FTIR), and the biochar FTIR spectra were obtained from pressed pellets of 1:10 biochar/KBr mixtures using a PerkinElmer Pyris Diamond (PerkinElmer, Waltham, Massachusetts, USA). The pellets were then scanned in the reflectance mode in the range 4000~500 cm⁻¹. A detailed account of the peak assignments of FTIR spectra refers to the reports of Keiluweit et al. [1] and Shen et al. [2].

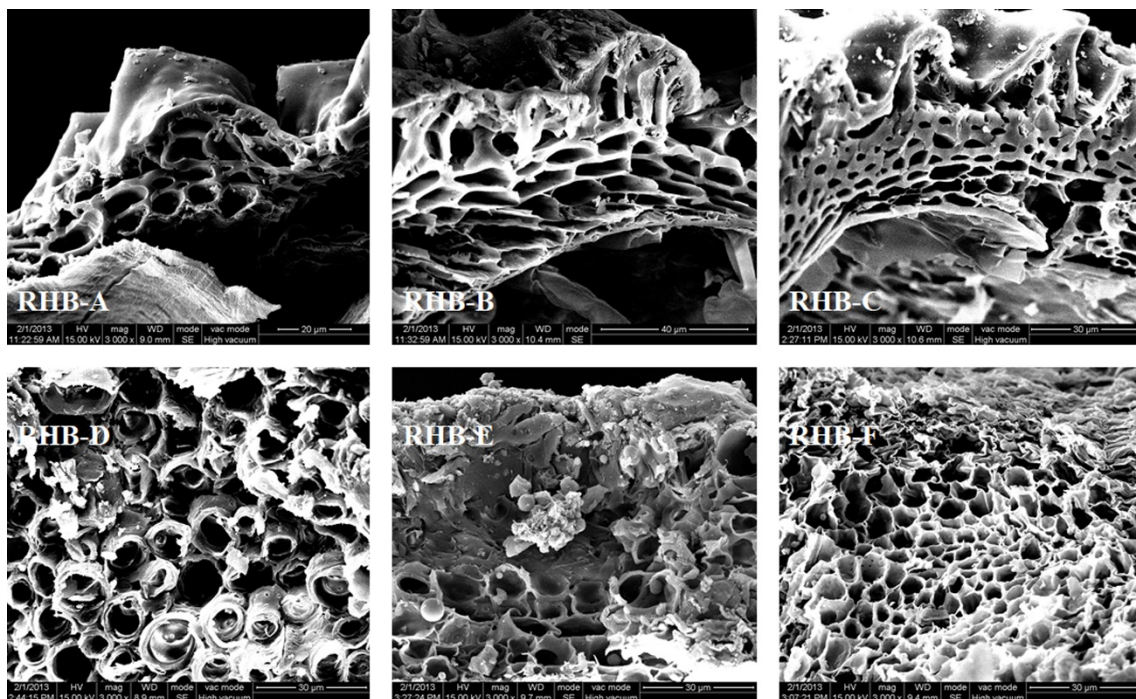
References

1. Keiluweit, M.; Nico, P.S.; Johnson, M.G.; Kleber, M., Dynamic molecular structure of plant biomass-derived black carbon (biochar). *Environ. Sci. Technol.* 2010, 44, 1247-1253.
2. Shen, Z.; Zhang, Y.; McMillan, O.; Jin, F.; Al-Tabbaa, A. Characteristics and mechanisms of nickel adsorption on biochars produced from wheat straw pellets and rice husk. *Environ. Sci. Pollut. Res. Int.* 2017, 24, 12809-12819.

Supplemental Figure S1. Results of significant tests of RHB effect on cumulative C release, soil properties and available nutrients within three studies soils.

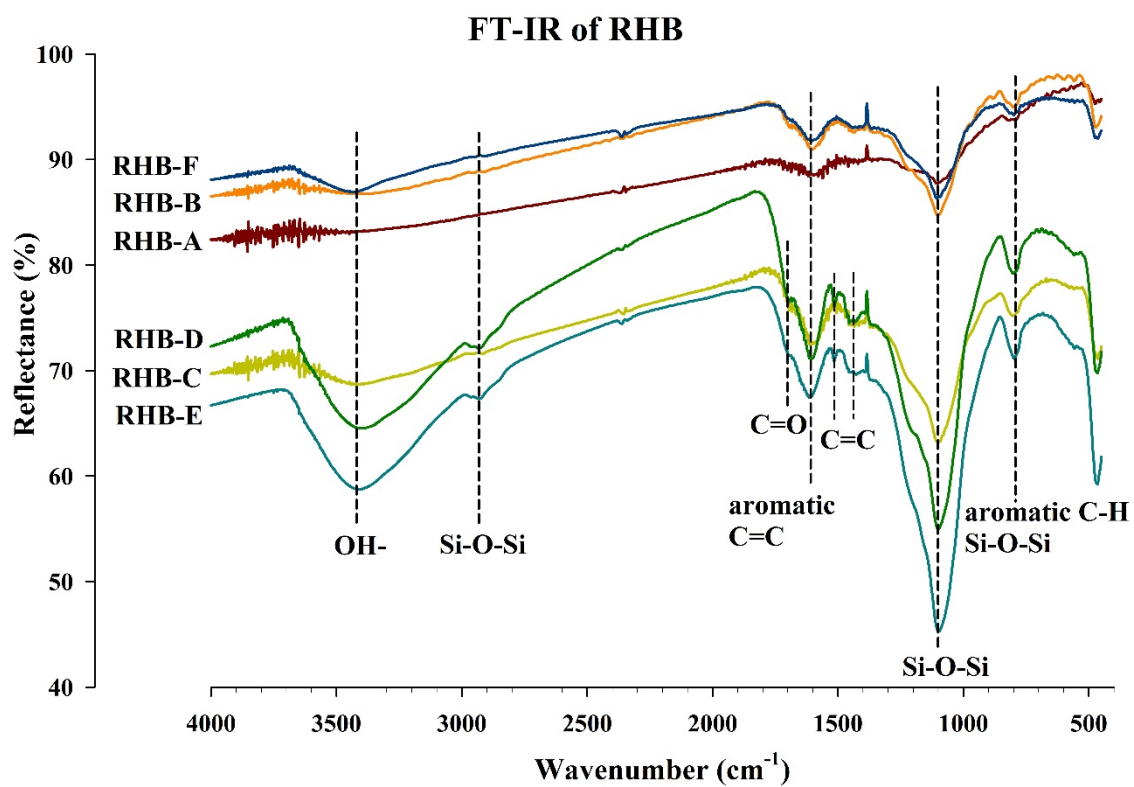
Supplemental Figure S2. Pearson correlation coefficients between measured parameters and PCs (PC1 and PC2) at Day 100 for the three studied soils.

Supplemental Figure S3. Canonical scores of the first two canonical discriminant functions (Can) of RHB type (A~F) and addition rate (0.5, 1.0, 4.0, 10, and 20%) in 3S, 14S and 24S soil. (C = control, CO = compost, A-0.5 = 0.5% of RHB A, and so on.)



Supplemental Figure S1. SEM images of the studied rice husk biochars.

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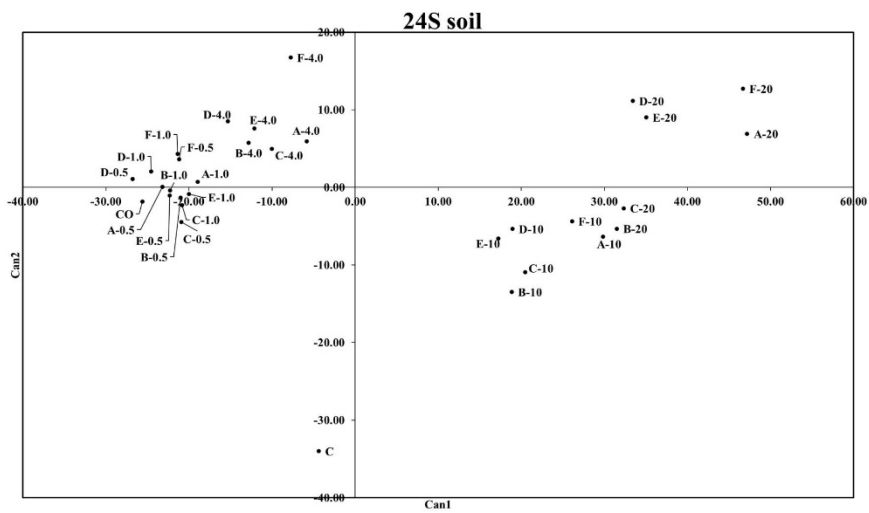
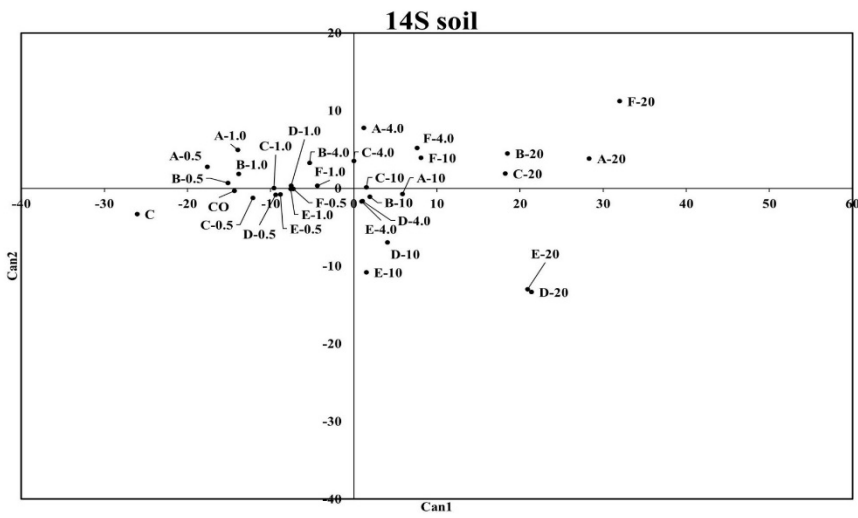
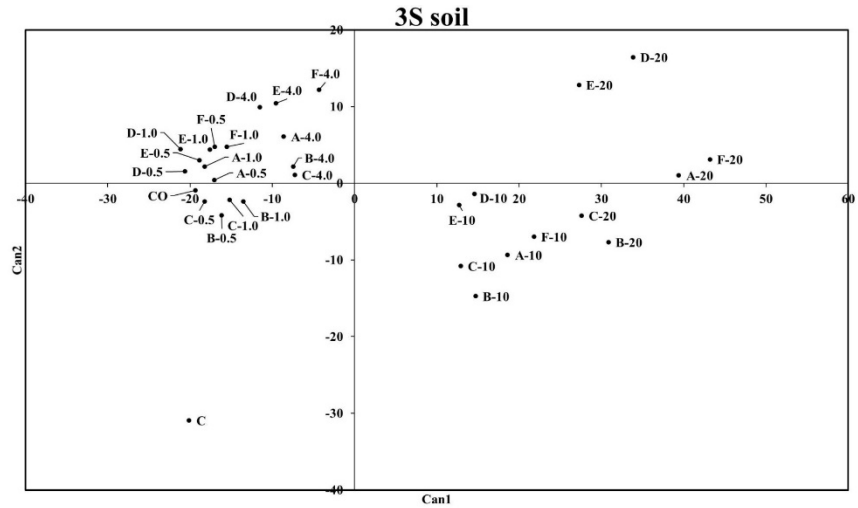
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Supplemental Figure S2. The FT-IR spectra of studied rice husk biochars.

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Supplemental Figure S3. Canonical scores of the first two canonical discriminant functions (Can) of RHB type (A~F) and addition rate (0.5, 1.0, 4.0, 10, and 20%) in 3S, 14S and 24S soil. (C = control, CO = compost, A-0.5 = 0.5% of RHB A, and so on.)

1 **Supplemental Table**

2

3 **Title: Effects of Rice Husk Biochar on Carbon Release and Nutrient**

4 **Availability in Three Cultivation Age of Greenhouse Soils**

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11 **Supplemental Table S1.** Pearson correlation coefficients between measured parameters
12 and PCs (PC1 and PC2) at Day 100 for the three studied soils.

13 **Supplemental Table S2.** Results of significant tests of RHB effect on cumulative C
14 release, soil properties and available nutrients within three studies soils.

15 **Supplemental Table S3.** Results of significant test of RHB effect on cumulative C
16 release, soil properties and available nutrients within five application rates.

Supplemental Table S1. Pearson correlation coefficients between measured parameters and PCs (PC1 and PC2) at Day 100 for the three studied soils.

Parameter	3S soil		14S soil		24S soil	
	PC1	PC2	PC1	PC2	PC1	PC2
Total variance	58.6%	16.0%	55.1%	12.2%	55.8%	12.9%
Cumulative C release	-0.431* ²	0.609*	-0.565*	0.394*	-0.162	0.819*
pH	-0.734*	0.542*	-0.646*	0.618*	-0.868*	0.142
EC ¹	0.614*	0.437*	-0.691*	-0.314	-0.172	-0.527*
TC	-0.839*	0.281	-0.878*	0.350	-0.884*	0.061
TN	0.961*	0.095	0.944*	0.191	0.951*	0.074
TP	0.735*	0.217	0.777*	0.122	0.745*	0.209
CEC	-0.443*	0.565*	-0.522*	-0.046	-0.270	0.639*
P	0.894*	0.335	0.938*	0.209	0.954*	0.122
K	-0.755*	0.543*	-0.569*	0.761*	-0.585*	0.502*
Ca	0.120	0.519*	-0.748*	-0.268	-0.278	-0.278
Mg	0.811*	0.465*	0.598*	0.047	0.893*	0.170
Cu	0.953*	0.070	0.892*	0.223	0.951*	0.016
Pb	0.957*	0.142	0.394*	0.380	0.848*	0.055
Zn	0.933*	0.103	0.945*	0.078	0.969*	0.053

¹ EC = electrical conductivity; TC = total carbon; TN = total nitrogen; TP = total phosphorus; CEC = cation exchange capacity; ² The asterisks after the data indicate the significant correlations analyzed by SAS ($P < 0.0001$).

Supplemental Table S2. Results of significant tests of RHB effect on cumulative C release, soil properties and available nutrients within three studies soils.

Soil	n	Cumulative C release	pH	EC ¹	TC	TN	TP	CEC	P	K	Ca	Mg	Cu	Pb	Zn
		mg CO ₂ -C kg ⁻¹ soil ⁻¹		dS m ⁻¹	%	g kg ⁻¹	g kg ⁻¹	coml (+) kg ⁻¹ soil ⁻¹	g kg ⁻¹	g kg ⁻¹	g kg ⁻¹	g kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹
RHB-A															
3S	15 ²	2919 B ³	5.11 C	1.17 B	5.37 A	2.17 A	1.97 B	16.5 C	1.01 B	1.00 B	2.29 C	0.42 C	5.64 B	9.25 A	50.3 C
14S	15	2574 C	5.24 B	2.41 A	5.26 A	1.95 AB	3.76 A	17.5 B	2.39 A	1.24 A	4.23 B	0.81 A	4.72 C	0.97 C	79.5 A
24S	15	3280 A	6.10 A	1.17 B	5.15 A	1.85 B	3.80 A	18.3 A	2.44 A	1.23 A	5.40 A	0.63 B	7.51 A	3.02 B	68.3 B
RHB-B															
3S	15	2834 B	5.10 C	1.13 B	5.75 A	2.07 A	2.15 C	17.0 B	1.03 C	0.90 B	2.49 C	0.43 C	4.63 B	7.56 A	39.7 B
14S	15	2394 C	5.19 B	2.29 A	5.29 B	1.77 B	3.90 B	17.8 A	2.33 B	1.08 A	4.93 B	0.81 A	4.15 C	0.38 C	67.8 A
24S	15	3443 A	5.99 A	1.13 B	5.12 B	1.77 B	4.06 A	18.0 A	2.48 A	1.05 A	5.15 A	0.61 B	7.08 A	2.21 B	69.2 A
RHB-C															
3S	15	2863 B	5.11 C	1.13 C	5.55 A	2.03 B	2.46 B	16.5 B	1.09 C	0.89 B	2.70 C	0.43 C	5.15 B	7.92 A	40.7 C
14S	15	2530 C	5.22 B	2.05 A	5.19 B	1.79 C	3.91 A	18.0 A	2.23 B	1.07 A	5.37 B	0.71 A	4.50 C	0.71 C	70.0 B
24S	15	3124 A	5.97 A	1.23 B	5.48 A	2.31 A	3.80 A	18.2 A	2.35 A	1.05 A	6.29 A	0.62 B	7.90 A	3.01 B	72.7 A
RHB-D															
3S	15	4239 B	5.04 C	1.09 C	4.46 A	2.16 A	2.11 B	16.9 B	1.01 C	0.92 B	2.92 B	0.43 C	6.13 B	9.00 A	47.1 B
14S	15	3505 C	5.17 B	1.87 A	4.27 A	2.28 A	3.74 A	17.2 B	2.44 B	1.17 A	5.04 A	0.69 A	5.05 C	0.77 C	75.1 A
24S	15	5180 A	5.89 A	1.12 B	4.20 A	2.18 A	3.70 A	18.3 A	2.57 A	1.18 A	5.18 A	0.63 B	6.60 A	1.93 B	74.3 A
RHB-E															
3S	15	4190 B	5.02 C	1.18 B	4.51 A	2.14 A	2.20 C	16.9 B	1.13 B	0.96 B	2.60 C	0.49 C	5.53 B	8.71 A	47.3 C
14S	15	3558 C	5.19 B	1.95 A	4.35 A	2.06 A	3.61 B	17.9 A	2.49 A	1.20 A	4.66 B	0.77 A	4.31 C	0.53 C	75.9 A
24S	15	4632 A	5.95 A	1.17 B	4.30 A	2.08 A	4.54 A	18.1 A	2.52 A	1.18 A	5.78 A	0.67 B	7.12 A	2.36 B	69.3 B
RHB-F															
3S	15	3180 B	5.18 C	1.22 B	5.78 A	2.09 A	2.19 C	17.1 A	1.12 C	1.12 C	2.72 C	0.46 B	5.64 B	9.10 A	49.3 C
14S	15	2674 C	5.30 B	2.01 A	5.14 B	1.76 B	4.25 B	17.3 A	2.49 B	1.40 A	4.80 B	0.74 A	4.47 C	0.66 C	76.9 A
24S	15	3586 A	6.07 A	1.27 B	5.65 A	2.17 A	4.90 A	17.4 A	2.67 A	1.36 B	5.89 A	0.69 A	7.05 A	2.48 B	70.1 B

¹ EC = electrical conductivity; TC = total carbon; TN = total nitrogen; TP = total phosphorus; CEC = cation exchange capacity; available nutrients (P, K, Ca, Mg, Cu, Pb and Zn) = Mehlich 3 extraction method; ² The value is means of five application rate for each RHB (in 3 replicates); ³ Means followed by 18 different capital letter are significantly different for each parameter between three soils (P < 0.01).

Supplemental Table S3. Results of significant test of RHB effect on cumulative C release, soil properties and available nutrients within five application rates.

Treatment		Cumulative C release	pH	EC ¹	TC	TN	TP	CEC	P	K	Ca	Mg	Cu	Pb	Zn
RHB	Rate	mg CO ₂ -C kg ⁻¹ soil ⁻¹		dS m ⁻¹	%	g kg ⁻¹	g kg ⁻¹	coml (+) kg ⁻¹ soil ⁻¹	g kg ⁻¹	g kg ⁻¹	g kg ⁻¹	g kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹	mg kg ⁻¹
RHB-A	0.5%	2632 D ²	5.24 E	1.61 A	2.75 D	3.09 A	3.80 A	17.4 A	2.36 A	0.79 C	3.88 B	0.70 A	7.85 A	5.58 A	83.1 A
	1.0%	2541 D	5.28 D	1.58 AB	2.93 D	3.23 A	3.75 A	17.4 A	2.32 A	0.84 C	3.82 B	0.70 A	7.60 A	5.98 A	85.8 A
	4.0%	2825 C	5.36 C	1.54 B	4.03 C	2.95 A	3.68 A	17.3 A	2.25 A	1.17 B	3.86 B	0.67 A	7.96 A	6.80 A	81.3 A
	10%	3049 B	5.65 B	1.58 AB	6.45 B	0.33 B	2.37 B	17.6 A	1.43 B	1.22 B	4.29 A	0.53 B	3.27 B	1.77 B	42.0 B
	20%	3574 A	5.88 A	1.60 A	10.1 A	0.34 B	2.26 B	17.6 A	1.37 B	1.77 A	4.02 AB	0.50 B	3.10 B	1.93 B	37.8 B
RHB-B	0.5%	2662 C	5.23 D	1.50 A	2.87 D	2.91 A	4.01 A	17.1 CD	2.32 A	0.79 D	4.10 B	0.71 A	6.61 A	4.40 A	75.1 A
	1.0%	2816 B	5.24 D	1.53 A	2.97 D	3.06 A	3.86 A	16.8 D	2.31A	0.83 D	4.12 B	0.70 A	6.50 A	4.32 A	72.6 A
	4.0%	3112 A	5.29 C	1.54 A	4.21 C	2.76 A	3.97 A	17.6 BC	2.29 A	1.07 B	3.78 C	0.70A	6.78 A	4.81 A	71.9 A
	10%	2853 B	5.59 B	1.54 A	6.56 B	0.32 B	2.71 B	18.1 AB	1.42 B	1.00 C	4.68 A	0.51 B	3.39 B	1.63 B	38.4 B
	20%	3010 A	5.77 A	1.48 A	10.3 A	0.31 B	2.30 C	18.2 A	1.40 B	1.37 A	4.27 B	0.47 C	3.16 B	1.76 B	36.7 B
RHB-C	0.5%	2692 B	5.23 D	1.52 B	2.82 D	3.38 A	3.76 A	17.0 B	2.23 AB	0.76 C	4.51 B	0.67 A	7.28 A	5.42 A	71.4 B
	1.0%	2800 B	5.32 C	1.41 C	3.00 D	3.03 B	3.81 A	17.3 B	2.26 A	0.78 C	4.54 B	0.64 B	7.43 A	4.94 B	74.0 A
	4.0%	2758 B	5.34 C	1.30 D	4.33 C	3.16 B	3.84 A	17.1 B	2.20 B	1.04 B	4.20 B	0.63 B	7.13 A	4.93 B	71.7 B
	10%	2879 B	5.57 B	1.61 A	6.83 B	0.33 C	3.06 B	17.6 B	1.41 C	1.03 B	5.56 A	0.52 C	3.83 B	2.00 C	45.0 C
	20%	3066 A	5.71 A	1.50 B	10.0 A	0.30 C	2.49 C	18.9 A	1.37 C	1.40 A	5.13 A	0.47 D	3.57 B	2.09 C	43.6 C
RHB-D	0.5%	3124 D	5.20 D	1.27 C	2.56 D	3.26 B	3.76 AB	16.6 C	2.34 A	0.78 D	4.26 BC	0.61 B	7.74 A	5.33 A	79.6 A
	1.0%	3233 D	5.19 D	1.26 C	2.80 D	3.69 A	3.94 A	16.6 C	2.37 A	0.83 C	4.09 BC	0.61 AB	7.29 B	4.87 B	78.6 A
	4.0%	3763 C	5.28 C	1.24 C	3.73 C	3.32 B	3.66 B	16.9 BC	2.36 A	1.10 B	3.89 C	0.63 A	7.24 B	4.92 B	75.8 B
	10%	4663 B	5.48 B	1.55 A	5.41 B	0.37 C	2.32 C	17.7 B	1.48 B	1.12 B	5.05 A	0.53 C	3.82 C	2.15 C	47.2 C
	20%	6756 A	5.67 A	1.48 B	7.03 A	0.38 C	2.25 C	19.6 A	1.48 B	1.64 A	4.62 AB	0.53 C	3.54 D	2.23 C	46.2 C
RHB-E	0.5%	3137 D	5.29 D	1.31 B	2.70 D	3.36 A	3.68 A	16.9 C	2.43 A	0.84 D	4.05 C	0.68 A	7.15 A	5.12 A	75.8 A
	1.0%	3302 D	5.30 D	1.30 B	2.80 D	3.22 A	3.49 A	17.2 BC	2.44 A	0.88 C	4.27 BC	0.68 A	6.98 AB	4.93 A	75.8 A
	4.0%	3892 C	5.35 C	1.27 B	3.94 C	3.19 A	3.56 A	17.3 BC	2.43 A	1.12 B	4.16 BC	0.68 A	6.88 B	4.98 A	75.1 A
	10%	4492 B	5.45 B	1.66 A	5.10 B	0.35 B	3.14 A	18.1 AB	1.47 B	1.10 B	4.87 A	0.57 C	3.67 C	2.03 C	48.6 B
	20%	5811 A	5.56 A	1.63 A	7.39 A	0.36 B	3.39 A	18.7 A	1.46 B	1.62 A	4.39 B	0.59 B	3.59 C	2.28 B	45.8 C
RHB-F	0.5%	3143 B	5.33 CD	1.31 C	2.75 D	3.31 A	4.76 A	17.3 A	2.48 A	0.90 E	4.43 BC	0.70 A	7.04 A	5.15 B	78.2 A
	1.0%	3173 B	5.31 D	1.32 C	2.89 D	2.95 B	4.18 A	17.4 A	2.53 A	0.98 D	3.98 C	0.71 A	7.20 A	5.40 A	78.2 A
	4.0%	3374 A	5.37 C	1.45 B	4.09 C	3.02 B	4.12 A	17.4 A	2.51 A	1.36 B	3.99 C	0.68 A	7.09 A	5.54 A	77.7 A
	10%	2944 C	5.66 B	1.72 A	7.02 B	0.36 C	2.83 B	16.6 B	1.47 B	1.30 C	5.16 A	0.53 B	3.64 B	1.97 D	47.7 B
	20%	3100 B	5.92 A	1.71 A	10.9 A	0.39 C	3.01 B	17.6 A	1.47 B	1.93 A	4.80 AB	0.54 B	3.62 B	2.34 C	45.4 C

¹ EC = electrical conductivity; TC = total carbon; TN = total nitrogen; TP = total phosphorus; CEC = cation exchange capacity; available nutrients (P, K, Ca, Mg, Cu, Pb and Zn) = Mehlich 3 extraction method; ² The value is means (n=9) of three soils for each addition rate (in 3 replicates). Means followed by different capital letter are significantly different for each parameter between treatments (P < 0.01).