

Biochar application improved sludge-amended landscape soil fertility
index but with no added benefit in plant growth

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Table S1 The properties of soil, SS and biochar

Parameters	soil	SS	SB	LB	RB
pH	5.77	7.52	10.28	12.53	12.91
Bulk density ($\text{g}\cdot\text{cm}^{-3}$)	1.31	0.84	/	/	/
Soil water content ($\text{g}\cdot\text{kg}^{-1}$)	154.69	702.68	/	/	/
organic matter ($\text{g}\cdot\text{kg}^{-1}$)	15.41	96.54	/	/	/
Total nitrogen ($\text{g}\cdot\text{kg}^{-1}$)	0.70	7.35	/	/	/
Available nitrogen ($\text{mg}\cdot\text{kg}^{-1}$)	26.83	428.50	/	/	/
Total phosphorus ($\text{g}\cdot\text{kg}^{-1}$)	0.38	4.81	/	/	/
Olsen phosphorus ($\text{mg}\cdot\text{kg}^{-1}$)	15.27	611.08	/	/	/
Total potassium ($\text{g}\cdot\text{kg}^{-1}$)	2.71	6.43	/	/	/
Available potassium ($\text{mg}\cdot\text{kg}^{-1}$)	65.23	413.27	/	/	/
Cu ($\text{mg}\cdot\text{kg}^{-1}$)	17.31	423.66	122	14	31
Zn ($\text{mg}\cdot\text{kg}^{-1}$)	40.23	863.49	735	108	271
Pb ($\text{mg}\cdot\text{kg}^{-1}$)	29.56	48.51	23	4	17
Cd ($\text{mg}\cdot\text{kg}^{-1}$)	0.18	19.88	8	/	/
Ni ($\text{mg}\cdot\text{kg}^{-1}$)	10.10	47.96	53	248	233
N (%)	/	/	0.601	1.255	0.86
C (%)	/	/	11.779	66.705	64.29
H (%)	/	/	0.851	3.48	2.12
Carbon-nitrogen ratio	/	/	19.598	53.1409	74.76
Carbon-hydrogen ratio	/	/	13.8407	19.1658	30.33
Cation exchange capacity ($\text{cmol}\cdot\text{kg}^{-1}$)	/	/	11.25	21.57	30.35
Specific surface area ($\text{m}^2\cdot\text{g}^{-1}$)	/	/	13.14	2.08	0.09
Total pore volume ($\text{cm}^3\cdot\text{g}^{-1}$)	/	/	0.0896	0.0133	0.0094
Average pore diameter (nm)	/	/	24.1987	34.7216	58.64

Note: "/" indicates no value. The National Standardization of China (GB/T23486-2009) sets the maximum permissible contents for PTEs in sludge for use in gardens or parks (Cu [$800 \text{ mg}\cdot\text{kg}^{-1}$], Zn [$2000 \text{ mg}\cdot\text{kg}^{-1}$], Pb [$300 \text{ mg}\cdot\text{kg}^{-1}$], Cd [$5.0 \text{ mg}\cdot\text{kg}^{-1}$], and Ni [$100 \text{ mg}\cdot\text{kg}^{-1}$]). The PTEs of the sludge used in this study did not exceed the standard.

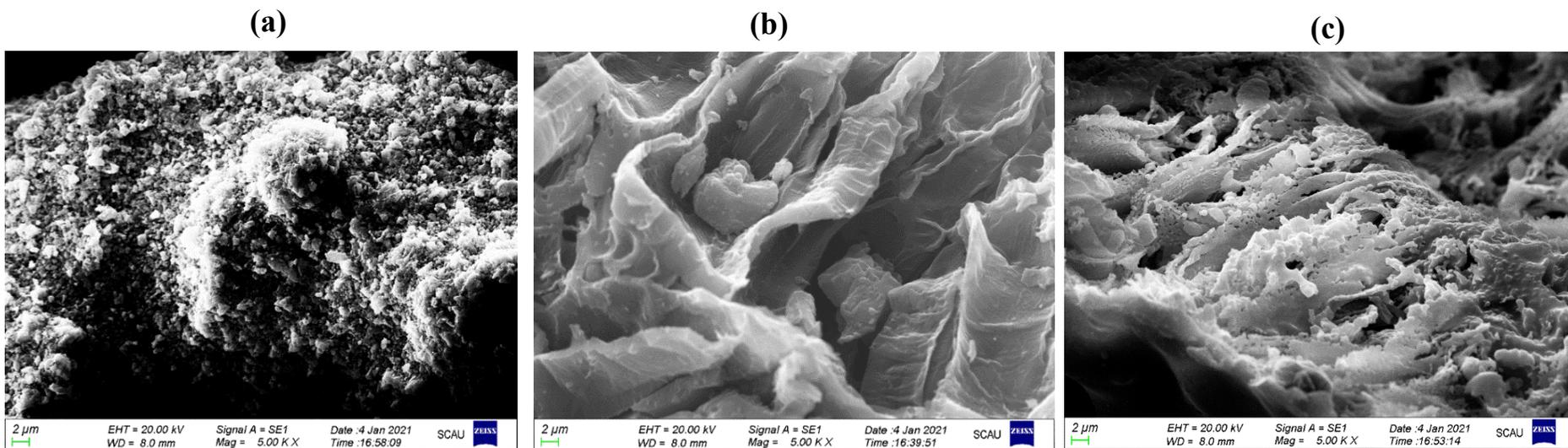


Figure S1. Scanning electron microscopy images of SB (a), LB (b), and RB (c) which were produced at 500°C temperature (scale for measuring scanning electron microscopy was 2.0 μm). SB = sewage sludge-derived biochar; LB= forest litter-derived biochar; and RB = rice straw-derived biochar.

Table S2 The representative meanings of each indicator

First, equations (2) and (3) were used to normalize the minimum or maximum values of data representing multiple indicators, which were used for normalization processing to obtain a standardized decision matrix using the vector normalization method. Subsequently, equations (4), (5), and (6) were used to calculate the entropy weights of the evaluation indicators, and the normalized decision matrix is multiplied by the weights of the evaluation indicators to obtain a weighted decision matrix. The normalized decision matrix was multiplied by the weights of the evaluation indicators and equation (7) is used to obtain the weighted decision matrix. Using equations (8) and (9), based on the optimal vector Z^+ and the worst vector Z^- of the weighted decision matrix, the optimal and worst solutions were obtained. where Z_{ij} is the weighted normalized value of the i -th index and the j -th treatment, and Z_i^+ and Z_i^- are the maximum and minimum values of the i -th index in different treatments, respectively. The relative closeness degree (C_j) between different treatment combination schemes. According to equations (10) and (11), the distances D^+ and D^- were calculated from the ideal value to the negative ideal value for each scheme and the queuing indicator value C_i was calculated (i.e., comprehensive evaluation index) for each production area according to equation (12). The closer the value of C_i is to 1, the better the comprehensive evaluation.

Table S3 The effects of biochar addition on SS-amended soil physical properties.

Treatments	Bulk density (g·cm ⁻³)	Capillary capacity (g·kg ⁻¹)	Total porosity (%)	Capillary porosity (%)	Noncapillary porosity (%)	pH	SOM (g·kg ⁻¹)	TN (g·kg ⁻¹)	AN (mg·kg ⁻¹)	TP (g·kg ⁻¹)	AP (mg·kg ⁻¹)	TK (g·kg ⁻¹)	AK (mg·kg ⁻¹)
CK	1.07±0.03Aa	528.78±26.16Aa	59.65±1.26Aa	56.41±1.94 Aa	3.24±2.22 Aa	7.48±0.07 Aa	67.43±6.7Aa	4.03±0.07Ba	228.21±0.88Aa	2.60±0.04Ba	313.13±17.23Ba	4.58±0.41Aa	239.25±6.29Aa
SB1.5	1.01±0.03Aa	510.44±34.52Aa	61.73±1.3Aa	51.61±2.7 Aa	10.12±2.69 Aa	7.6±0.01 Aa	68.61±5.42Ab	4.38±0.19ABb	228.29±1.18Aa	2.50±0.09Bb	231.26±2.79Cb	4.17±0.49Ab	196.20±15.51Bb
SB3.0	1.01±0.02Aa	581.33±5.27Aa	61.96±0.58Aa	58.61±1.41 Aa	3.35±1.98 Aa	7.56±0.02 Aa	61.4±0.74Ab	4.24±0.09ABb	229.49±4.26Aa	2.62±0.01Bb	388.52±10.42Aa	4.42±0.28Ac	212.65±3.64ABc
SB4.5	0.99±0.03Aa	451.87±72.12Aa	62.8±1.02Ab	44.59±7.41 Aa	18.2±7.74 Aa	7.6±0.02 Aa	66.28±4.2Ab	4.61±0.21Aab	230.03±5.25Aab	2.87±0.08Ab	241.68±8.49Cb	4.29±0.09Ac	237.66±16.61Ac
CK	1.07±0.03Aa	528.78±26.16Aa	59.65±1.26Ba	56.41±1.94 Aa	3.24±2.22 Aa	7.48±0.07 Aa	67.43±6.7Ba	4.03±0.07Ba	228.21±0.88ABa	2.60±0.04Ba	313.13±17.23Ba	4.58±0.41Ba	239.25±6.29Da
LB1.5	0.97±0.03Ba	564.11±98.94Aa	63.48±1.00Aa	54.08±8.00 Aa	9.4±7.04 Aa	7.60±0.02 Aa	80.48±2.62ABa	4.95±0.13Aa	220.60±9.10Ba	2.98±0.07Aa	385.29±11.18Aa	4.88±0.26ABab	523.35±15.18Ca
LB3.0	0.92±0.01Ba	640.2±35.69Aa	65.42±0.43 Aa	58.67±3.42 Aa	6.75±3.58 Aa	7.62±0.01 Aa	79.94±6.86ABa	5.42±0.29Aa	219.45±6.27Ba	3.07±0.03Aa	364.80±6.27Aa	5.63±0.02Ab	819.93±8.12Ba
LB4.5	0.92±0.01Bab	567.79±77.8Aa	65.25±0.41Aab	52.44±7.65 Aa	12.82±8.02 Aa	7.58±0.03 Aa	93.74±5.18Aa	5.39±0.28Aa	241.38±2.20Aa	3.01±0.04Aab	206.58±3.12Cc	5.74±0.35Ab	1185.42±13.9Aa
CK	1.07±0.03Aa	528.78±26.16Aa	59.65±1.26Ba	56.41±1.94 Aa	3.24±2.22 Aa	7.48±0.07 Aa	67.43±6.7Aa	4.03±0.07Ba	228.21±0.88Aa	2.60±0.04Ba	313.13±17.23Ba	4.58±0.41Ba	239.25±6.29Ca
RB1.5	0.96±0.04ABa	637.76±60.99Aa	63.71±1.36ABa	60.92±3.49 Aa	2.79±2.34 Aa	7.59±0.02 Aa	64.83±4.53Aab	4.72±0.11Aab	226.11±1.04Aa	3.06±0.09Aa	370.17±5.04Aa	5.36±0.08Ba	537.14±34.08Ba
RB3.0	0.98±0.05ABa	611.66±48.66Aa	63.00±1.70ABa	59.58±2.79 Aa	3.41±2.33 Aa	7.57±0.03 Aa	56.18±1.69Ab	4.25±0.19ABb	222.20±2.14Aa	3.10±0.00Aa	372.3±11.84Aa	6.77±0.27Aa	500.04±47.60Bb
RB4.5	0.91±0.02ABb	661.90±14.52Aa	65.53±0.72Aa	60.42±0.69 Aa	5.11±1.05 Aa	7.52±0.01 Aa	60.04±3.44Ab	4.28±0.20ABb	223.89±3.39Ab	3.14±0.05Aa	365.85±2.49Aa	7.25±0.48Aa	867.05±33.65Ab

Note: Values are mean ± SE (n = 3). In the same type of biochar, different capital letters indicate significant differences between different application rates. At the same biochar application rate, different lowercase letters indicate significant differences between different types of biochar ($\alpha = 0.05$ by Tukey's HSD test).

TableS4 Calculate the weight of each indicator and obtain the target weight

Index	Weight coefficient	Index	Weight coefficient
Plant height	0.070882	CAT	0.074912
root length	0.067425	MDA	0.02048
biomass	0.026812	Shoot Cd content	0.02734
Shoot N content	0.036864	Shoot Pb content	0.024404
Shoot P content	0.026218	Shoot Cu content	0.025397
Shoot K content	0.030776	Shoot Zn content	0.023705
Root N content	0.057191	Shoot Ni content	0.018075
Root P content	0.027781	Root Cd content	0.073863
Root K content	0.044455	Root Pb content	0.049352
Root activity	0.045425	Root Cu content	0.039827
Soluble protein	0.051338	Root Zn content	0.033998
SOD	0.038825	Root Ni content	0.041241
POD	0.023415		