

1. Supplementary data Table 1. Rice growth and selected soil properties (pH, CEC, plant-available nutrients) of 24 experimental pots

Treatment	Biochar	Cow manure	Replicates	Aboveground biomass (g pot ⁻¹)	Root biomass (g pot ⁻¹)	pH	EC (dS m ⁻²)	Available P (mg kg ⁻¹)	NH ₄ ⁺ (mg kg ⁻¹)	NO ₃ ⁻ (mg kg ⁻¹)
1	No biochar	No	1	8.63	1.23	7.20	4.50	20.1	32.96	11.63
2	Rice husk biochar	No	1	9.42	0.97	7.10	4.21	36.9	42.66	21.33
3	Rice straw biochar	No	1	11.12	0.31	7.20	4.05	26.0	78.53	20.36
4	No biochar	Yes	1	2.54	0.14	7.20	3.11	32.7	87.62	43.63
5	Rice husk biochar	Yes	1	6.86	0.37	6.90	2.67	46.5	95.98	37.81
6	Rice straw biochar	Yes	1	5.38	0.40	7.20	3.91	35.4	61.08	20.36
1	No biochar	No	2	0.56	0.11	7.25	4.52	20.1	78.53	26.18
2	Rice husk biochar	No	2	9.66	1.01	6.95	5.10	36.6	46.54	20.36
3	Rice straw biochar	No	2	13.85	1.08	7.10	4.60	23.9	49.45	17.45
4	No biochar	Yes	2	6.60	0.68	7.15	5.31	62.5	68.70	20.36
5	Rice husk biochar	Yes	2	4.74	1.54	7.10	4.08	47.6	52.35	20.36
6	Rice straw biochar	Yes	2	5.23	0.32	7.15	4.71	65.0	77.56	7.76
1	No biochar	No	3	1.56	0.40	7.15	4.70	29.6	55.07	5.82
2	Rice husk biochar	No	3	11.91	1.27	7.10	5.02	33.6	17.45	5.82
3	Rice straw biochar	No	3	16.44	2.41	7.05	3.97	22.0	17.45	5.82
4	No biochar	Yes	3	5.18	0.45	7.05	4.45	36.3	46.54	9.70
5	Rice husk biochar	Yes	3	9.13	2.68	7.00	4.40	72.2	27.15	7.76
6	Rice straw biochar	Yes	3	4.72	0.89	7.15	4.85	33.9	40.72	7.76
1	No biochar	No	4	4.21	0.37	5.80	5.07	26.1	56.23	9.70
2	Rice husk biochar	No	4	10.63	0.79	6.55	4.29	41.7	40.72	11.63
3	Rice straw biochar	No	4	10.28	2.16	6.60	4.46	38.2	67.87	5.82
4	No biochar	Yes	4	5.27	0.38	6.50	4.55	36.2	56.23	3.88
5	Rice husk biochar	Yes	4	13.30	1.86	6.60	5.26	65.1	25.21	5.82
6	Rice straw biochar	Yes	4	5.60	1.69	6.70	4.99	48.8	40.72	3.88

2. Supplementary data Table 2. Soil CEC and concentration of exchangeable Na, K, Mg, Ca, and non-Na cation, as well as Cl⁻ of 24 experimental pots

Treat- ment	Biochar	Cow manure	Repli- cates	CEC cmol _c kg ⁻¹	Na cmol _c kg ⁻¹	K cmol _c kg ⁻¹	Mg cmol _c kg ⁻¹	Ca cmol _c kg ⁻¹	Non-Na cations cmol _c kg ⁻¹	Cl ⁻ mg kg ⁻¹
1	No biochar	No	1	25.37	8.48	2.62	1.89	3.86	16.89	4877
2	Rice husk biochar	No	1	27.76	9.06	5.06	2.32	4.03	18.70	4254
3	Rice straw biochar	No	1	28.17	8.78	4.99	2.17	3.19	19.39	4032
4	No biochar	Yes	1	24.07	7.84	3.43	1.84	3.85	16.23	3634
5	Rice husk biochar	Yes	1	25.86	7.78	5.35	2.06	3.92	18.08	3656
6	Rice straw biochar	Yes	1	29.98	7.87	5.36	2.70	3.37	22.10	3545
1	No biochar	No	2	22.44	8.87	2.91	1.48	4.24	13.57	2927
2	Rice husk biochar	No	2	28.66	10.36	5.23	1.46	4.69	18.31	5207
3	Rice straw biochar	No	2	29.21	9.41	4.78	1.61	4.16	19.80	4232
4	No biochar	Yes	2	25.31	9.79	3.18	1.92	3.33	15.52	4786
5	Rice husk biochar	Yes	2	25.83	8.09	5.05	1.84	4.03	17.75	4055
6	Rice straw biochar	Yes	2	28.23	7.77	5.56	2.60	3.26	20.46	3897
1	No biochar	No	3	23.57	8.10	3.06	2.07	3.43	15.47	4522
2	Rice husk biochar	No	3	27.14	10.42	4.08	1.89	3.74	16.72	4852
3	Rice straw biochar	No	3	28.76	9.08	4.87	1.72	3.48	19.68	4476
4	No biochar	Yes	3	28.35	11.24	3.76	2.47	3.60	17.11	4941
5	Rice husk biochar	Yes	3	34.13	10.41	7.38	2.43	4.95	23.72	4586
6	Rice straw biochar	Yes	3	29.29	9.53	5.44	2.14	4.19	19.75	4165
1	No biochar	No	4	26.90	8.91	2.94	1.84	4.84	18.00	4832
2	Rice husk biochar	No	4	28.55	9.51	4.99	1.63	4.88	19.03	4431
3	Rice straw biochar	No	4	27.64	9.51	5.39	1.13	5.07	18.13	4409
4	No biochar	Yes	4	28.98	10.98	3.70	1.33	5.13	18.00	4963
5	Rice husk biochar	Yes	4	33.73	11.16	7.09	0.62	6.89	22.56	5495
6	Rice straw biochar	Yes	4	29.45	10.12	6.58	0.04	6.52	19.33	4409

3. Statistical results

3.1. For aboveground biomass

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	
Model	8	267.98293	33.4979	4.6966	
Error	15	106.98652	7.1324	Prob > F	
C. Total	23	374.96945		0.0049*	

Parameter Estimates					
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Effect Tests					
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Replicate	3	3	8.67528	0.4054	0.7513
Biochar	2	2	131.15482	9.1943	0.0025*
Cow manure	1	1	47.37660	6.6424	0.0210*
Biochar*Cow manure	2	2	80.77623	5.6626	0.0147*

Because the interaction between biochar and cow manure is significant ($P=0.0147$), the main effects are not considered and the interactive effect is examined:

Tukey honestly significant difference test:

Biochar*Cow manure		
LSMeans Differences Tukey HSD		
Level		Least Sq Mean
Rice-straw biochar, Without cow manure	A	12.922500
Rice-husk biochar, Without cow manure	A B	10.405000
Rice-husk biochar, With cow manure	A B C	8.507500
Rice-straw biochar, With cow manure	B C	5.232500
No biochar, With cow manure	B C	4.897500
No biochar, Without cow manure	C	3.740000
Levels not connected by same letter are significantly different.		

3.2. Root biomass:

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Model	8	7.206983	0.900873	2.4982	
Error	15	5.409112	0.360607		
C. Total	23	12.616096			0.0602

Parameter Estimates					
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Effect Tests					
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Replicate	3	3	2.3594125	2.1810	0.1327
Biochar	2	2	3.2106583	4.4517	0.0304*
Cow manure	1	1	0.0210042	0.0582	0.8126
Biochar*Cow manure	2	2	1.6159083	2.2405	0.1408

The interaction is not significant ($P=0.14$), but the main effect of biochar is significant ($P=0.03$). Therefore, the interactive effect is not considered and main effect of biochar is examined:

Tukey honestly significant difference test for the main effect of biochar:

Biochar		
LSMeans Differences Tukey HSD		
Level		Least Sq Mean
Rice-husk biochar	A	1.3112500
Rice-straw biochar	A B	1.1575000
No biochar	B	0.4700000
Levels not connected by same letter are significantly different.		

3.3. Soil pH

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	
Model	8	2.0258333	0.253229	6.5314	
Error	15	0.5815625	0.038771	Prob > F	
C. Total	23	2.6073958		0.0010*	

Parameter Estimates					
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Effect Tests					
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Replicate	3	3	1.9253125	16.5529	<.0001*
Biochar	2	2	0.0602083	0.7765	0.4777
Cow manure	1	1	0.0176042	0.4541	0.5107
Biochar*Cow manure	2	2	0.0227083	0.2929	0.7503

➔ No effects (interactive and main effects) are significant. So we do not do Tukey honestly significant difference test for any effects

3.4. Soil EC:

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Model	8	6.2656167	0.783202	3.4674	
Error	15	3.3881667	0.225878		
C. Total	23	9.6537833			0.0182*

Parameter Estimates					
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Effect Tests					
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Replicate	3	3	4.6548833	6.8693	0.0039*
Biochar	2	2	0.4535583	1.0040	0.3898
Cow manure	1	1	0.3750000	1.6602	0.2171
Biochar*Cow manure	2	2	0.7821750	1.7314	0.2106

➔ No effects (interactive and main effects) are significant. So we do not do Tukey honestly significant difference test for any effects

3.5. NH_4^+

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	5575.972	696.996	2.1106
Error	15	4953.625	330.242	Prob > F
C. Total	23	10529.596		0.1011

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Replicate	3	3	3905.6779	3.9422	0.0294*
Biochar	2	2	1145.5975	1.7345	0.2101
Cow manure	1	1	386.4037	1.1701	0.2965
Biochar*Cow manure	2	2	138.2925	0.2094	0.8134

➔ No effects (interactive and main effects) are significant. So we do not do Tukey honestly significant difference test for any effects

3.6. NO₃⁻

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	1815.9667	226.996	4.5999
Error	15	740.2267	49.348	Prob > F
C. Total	23	2556.1933		0.0054*

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Replicate	3	3	1566.9533	10.5843	0.0005*
Biochar	2	2	143.5208	1.4542	0.2647
Cow manure	1	1	31.2817	0.6339	0.4384
Biochar*Cow manure	2	2	74.2108	0.7519	0.4884

➔ No effects (interactive and main effects) are significant. So we do not do Tukey honestly significant difference test for any effects

3.7. Soil exchangeable Mg

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Model	8	267710.89	33463.9	2.1666	
Error	15	231684.02	15445.6		
C. Total	23	499394.91			0.0937

Parameter Estimates					
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Effect Tests					
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Replicate	3	3	258717.46	5.5834	0.0089*
Biochar	2	2	2180.57	0.0706	0.9322
Cow manure	1	1	1424.50	0.0922	0.7655
Biochar*Cow manure	2	2	5388.36	0.1744	0.8416

➔ No effects (interactive and main effects) are significant. So we do not do Tukey honestly significant difference test for any effects

3.8. Soil Cl⁻

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Model	8	3401359.3	425170	1.4083	
Error	15	4528420.3	301895		
C. Total	23	7929779.6			0.2701

Parameter Estimates					
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Effect Tests					
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Replicate	3	3	2214205.5	2.4448	0.1042
Biochar	2	2	743460.3	1.2313	0.3198
Cow manure	1	1	35190.0	0.1166	0.7375
Biochar*Cow manure	2	2	408503.6	0.6766	0.5232

➔ No effects (interactive and main effects) are significant. So we do not do Tukey honestly significant difference test for any effects

3.9. Soil exchangeable Ca

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	15.954617	1.99433	5.7224
Error	15	5.227679	0.34851	Prob > F
C. Total	23	21.182296		0.0019*

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Replicate	3	3	13.269646	12.6917	0.0002*
Biochar	2	2	1.649008	2.3658	0.1279
Cow manure	1	1	0.490204	1.4066	0.2541
Biochar*Cow manure	2	2	0.545758	0.7830	0.4749

➔ No effects (interactive and main effects) are significant. So we do not do Tukey honestly significant difference test for any effects

3.10. Soil exchangeable Na

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	8	224291.19	28036.4	2.9153
Error	15	144256.05	9617.1	Prob > F
C. Total	23	368547.24		0.0353*

Parameter Estimates

Effect Tests

Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Replicate	3	3	146382.94	5.0737	0.0127*
Biochar	2	2	18397.35	0.9565	0.4065
Cow manure	1	1	2448.24	0.2546	0.6212
Biochar*Cow manure	2	2	57062.66	2.9667	0.0821

➔ No effects (interactive and main effects) are significant. So we do not do Tukey honestly significant difference test for any effects

3.11. Available P

Summary of Fit					
Analysis of Variance					
		Sum of			
Source	DF	Squares	Mean Square	F Ratio	
Model	8	347243.54	43405.4	4.1646	
Error	15	156338.86	10422.6	Prob > F	
C. Total	23	503582.40		0.0084*	
Parameter Estimates					
Effect Tests					
		Sum of			
Source	Nparm	DF	Squares	F Ratio	Prob > F
Replicate	3	3	38643.40	1.2359	0.3315
Biochar	2	2	92095.82	4.4181	0.0310*
Cow manure	1	1	215651.04	20.6907	0.0004*
Biochar*Cow manure	2	2	853.28	0.0409	0.9600

→ The interactive effect is not significant; but the main effects of biochar and cow manure are significant. So we do not do Tukey honestly significant difference test for the interaction but we do for the main effects

Biochar		
LSMeans Differences Tukey HSD		
		Least
Level		Sq Mean
Rice-husk biochar A		475.41250
Rice-straw biochar A B		366.46250
No biochar B		329.47500
Levels not connected by same letter are significantly different.		

Because two treatments are compared, the Student's t Test is applied

Cow manure		
LSMeans Differences Student's t		
Level		Least Sq Mean
With cow manure	A	485.24167
Without cow manure	B	295.65833
Levels not connected by same letter are significantly different.		

3.12. Soil exchangeable K

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	
Model	8	34.509933	4.31374	13.5203	
Error	15	4.785867	0.31906	Prob > F	
C. Total	23	39.295800		<.0001*	
Parameter Estimates					
Effect Tests					
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Replicate	3	3	1.750733	1.8291	0.1852
Biochar	2	2	27.099225	42.4676	<.0001*
Cow manure	1	1	5.005067	15.6870	0.0013*
Biochar*Cow manure	2	2	0.654908	1.0263	0.3822

➔ The interactive effect is not significant ($P=0.38$); but the main effects of biochar ($P<0.0001$) and cow manure ($P=0.0012$) are significant. So we do not do Tukey honestly significant difference test for the interaction but we do for the main effects

Biochar		
LSMeans Differences Tukey HSD		
Level		Least Sq Mean
Rice-husk biochar	A	5.5287500
Rice-straw biochar	A	5.3712500
No biochar	B	3.2000000
Levels not connected by same letter are significantly different.		

Cow manure		
LSMeans Differences Student's t		
Level		Least Sq Mean
With cow manure	A	5.1566667
Without cow manure	B	4.2433333
Levels not connected by same letter are significantly different.		

3.13. Soil CEC

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Model	8	102.67333	12.8342	2.7690	
Error	15	69.52500	4.6350		
C. Total	23	172.19833			0.0425*

Parameter Estimates					
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Effect Tests					
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Replicate	3	3	28.485000	2.0485	0.1503
Biochar	2	2	57.243333	6.1751	0.0111*
Cow manure	1	1	15.041667	3.2452	0.0918
Biochar*Cow manure	2	2	1.903333	0.2053	0.8166

➔ The interactive effect is not significant ($P=0.82$); but the main effect of biochar is significant. So we do not do Tukey honestly significant difference test for the interaction but we do for the biochar effect

Biochar		
LSMeans Differences Tukey HSD		
Level		Least Sq Mean
Rice-husk biochar	A	28.950000
Rice-straw biochar	A	28.850000
No biochar	B	25.625000

Levels not connected by same letter are significantly different.

3.14. Total exchangeable cations, excluding exchangeable Na (ECENa)

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Ratio	
Model	8	80.07598	10.0095	3.4496	
Error	15	43.52427	2.9016	Prob > F	
C. Total	23	123.60025		0.0186*	

Parameter Estimates					
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Effect Tests					
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Replicate	3	3	8.313783	0.9551	0.4392
Biochar	2	2	57.070075	9.8342	0.0019*
Cow manure	1	1	11.928600	4.1110	0.0608
Biochar*Cow manure	2	2	2.763525	0.4762	0.6302

→ The interactive effect is not significant ($P=0.63$); but the main effects of biochar ($P<0.0019$) is significant. So we do not do Tukey honestly significant difference test for the interaction but we do for the biochar effect

Biochar	
LSMeans Differences Tukey HSD	
Level	Least Sq Mean
Rice-straw biochar A	19.830000
Rice-husk biochar A	19.358750
No biochar B	16.348750
Levels not connected by same letter are significantly different.	