Short-term Effects of Biochar Addition on Nitrification, Ammonia Oxidizer and Nitrous Oxide Emissions in Two Acid Red Soils

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Nitrification is an important part of the soil N cycle (Figure 1). Ammonia oxidation is the first and rate-limiting step during nitrification, driven by ammonia-oxidizing bacteria (AOB) and archaea (AOA) (Jia and Conrad, 2009). Acid soil accounts for 37% of Chinese total agricultural land, and is faced with nutrient deficiencies. Biochar can be used to ameliorate soil acidity and improve soil fertility. Meanwhile, it may influence microbial growth and diversity, and subsequently disturb nitrification.

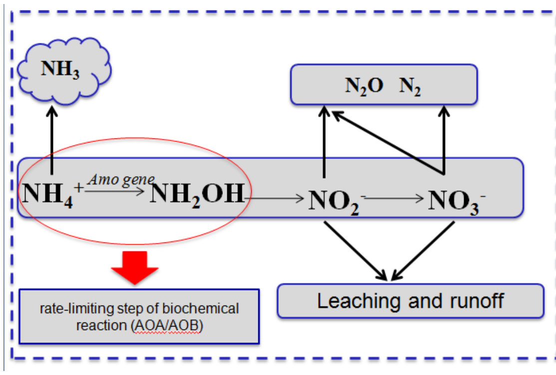

Figure 1. Transformation processes of NH_4^+ in the soil.

The impacts of rice-straw biochar (BC) applications on nitrification in two acid oxisols soils (red granite upland [RGU] and tertiary red sandstone upland [RTU]) were investigated using 56-day aerobic incubation. Six treatments: CK control with/without N (NH_4^+-N: 110 mg/kg), 1% BC with/without N (biochar: 1% (*w/w*)), 5% BC with/without N (biochar: 5% (*w/w*)) for each soil type were used. We combined soil NH_4^+ transformation processes with analysis of nitrification kinetics and ammonia oxidizer populations to examine the response of nitrification activity to biochar; N_2O emissions were monitored periodically during the incubation period. Results showed that biochar treatments consistently increased nitrification rate constants and high biochar application even altered nitrification patterns to first-order reaction model in the two soils (Figure 2, Table 1); 5% BC treatments of the two soils increased gene copy numbers of AOB (up to 7.88 and 14 times compared with CK in RGU and RTU), while there was little change or decreased gene copy numbers of AOA (Figure 3). Biochar enrichment reduced cumulative N_2O emissions (up to 37.6 and 46.4% in RGU and RTU) (Figure 4).

These results provide evidence that nitrifier activity was gradually restored in acid soils following high rates of the biochar application, to the extent that it was no longer the limiting factor for nitrification. AOB may play a key role in biochar-enhanced nitrification. The results of the present study will expand our understanding on the impacts of BC on N transformation processes.

References

Jia, Z.J., and R. Conrad. 2009. Bacteria rather than Archaea dominate microbial ammonia oxidation in an agricultural soil. Environ. Microbiol. 11: 1658–1671.

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Table 1. Kinetic model fitting of NO_3^-N accumulation over a 56-day incubation at 30°C and 65% water holding capacity in each treatment.

Soil	Treatment	Model	Np (mg N kg^{-1})	$^cK_0$ (mg N $kg^{-1}d^{-1}$) or k_1 (d^{-1})	R^2
RGU	CK	Zero-order		0.673 ± 0.085	0.755**
	1%BC	First-order	37.3	0.062± 0.021	0.764**
	5%BC	First-order	29.36	0.118 ± 0.032	0.791**
	CK+N	Zero-order		1.87 ± 0.116	0.970**
	1%BC+N	First-order	167.67	0.022± 0.013	0.946**
	5%BC+N	First-order	118.60	0.198 ± 0.05	0.947**
RTU	CK	Zero-order		0.112 ± 0.02	0.346*
	1%BC	Zero-order		0.286 ± 0.039	0.716**
	5%BC	First-order	28.313	0.036± 0.009	0.925**
	CK+N	Zero-order		0.241 ± 0.033	0.718**
	1%BC+N	Zero-order		0.323 ± 0.110	0.275**
	5%BC+N	First-order	79.07	0.049±0.007	0.964**

Notes: Zero order kinetic model and First-order kinetic model: N_t, NO_3^- concentration on day t (mg N kg^{-1} soil); N_0, initial concentration of NO_3^- (mg N kg^{-1} soil); N_p, potential net nitrification (mg N kg^{-1} soil) in first-order reaction model; k_0 (mg N kg^{-1} d^{-1}) and $k1$ (d^{-1}), nitrification rate constants for zero- and first-order reaction models, respectively.

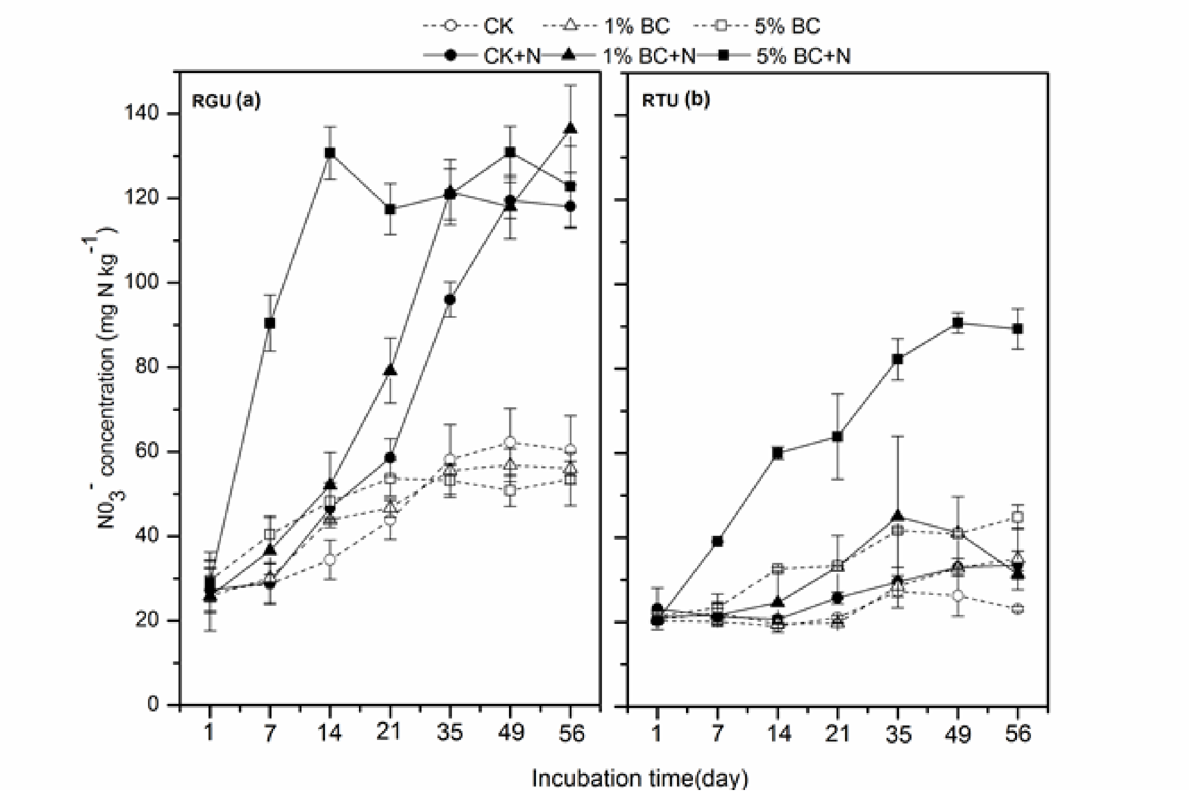

Figure 2. Nitrate (NO_3^-) nitrogen concentrations versus time over a 56-day incubation.

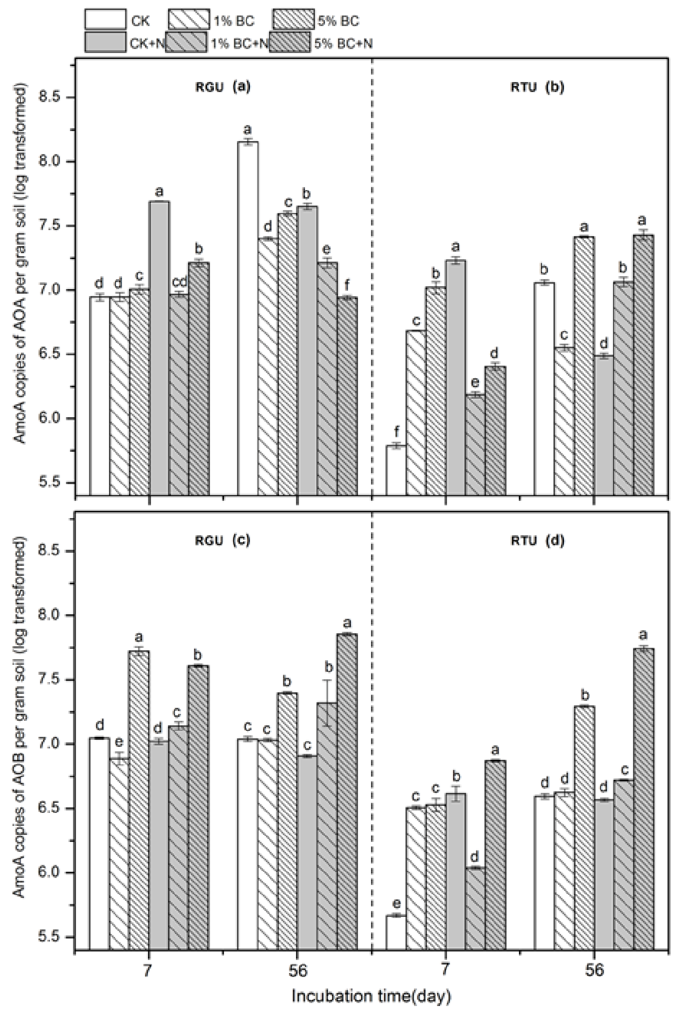

Figure 3. Archaeal (a, b) and bacterial (c, d) amoA gene copy numbers over a 56-day incubation.

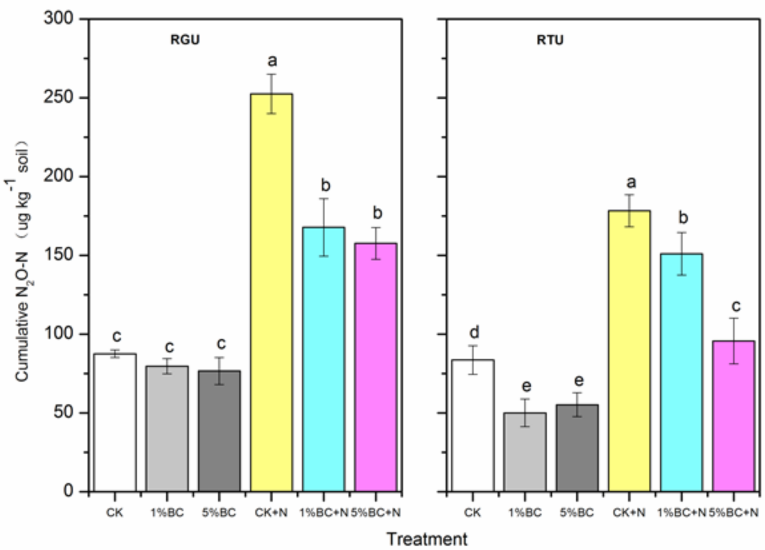

Figure 4. Cumulative N_2O emissions from RGU and RTU soils over a 56-day incubation.