Does long-term soil warming affect microbial element limitation? A test by short-term assays of microbial growth responses to labile C, N and P additions

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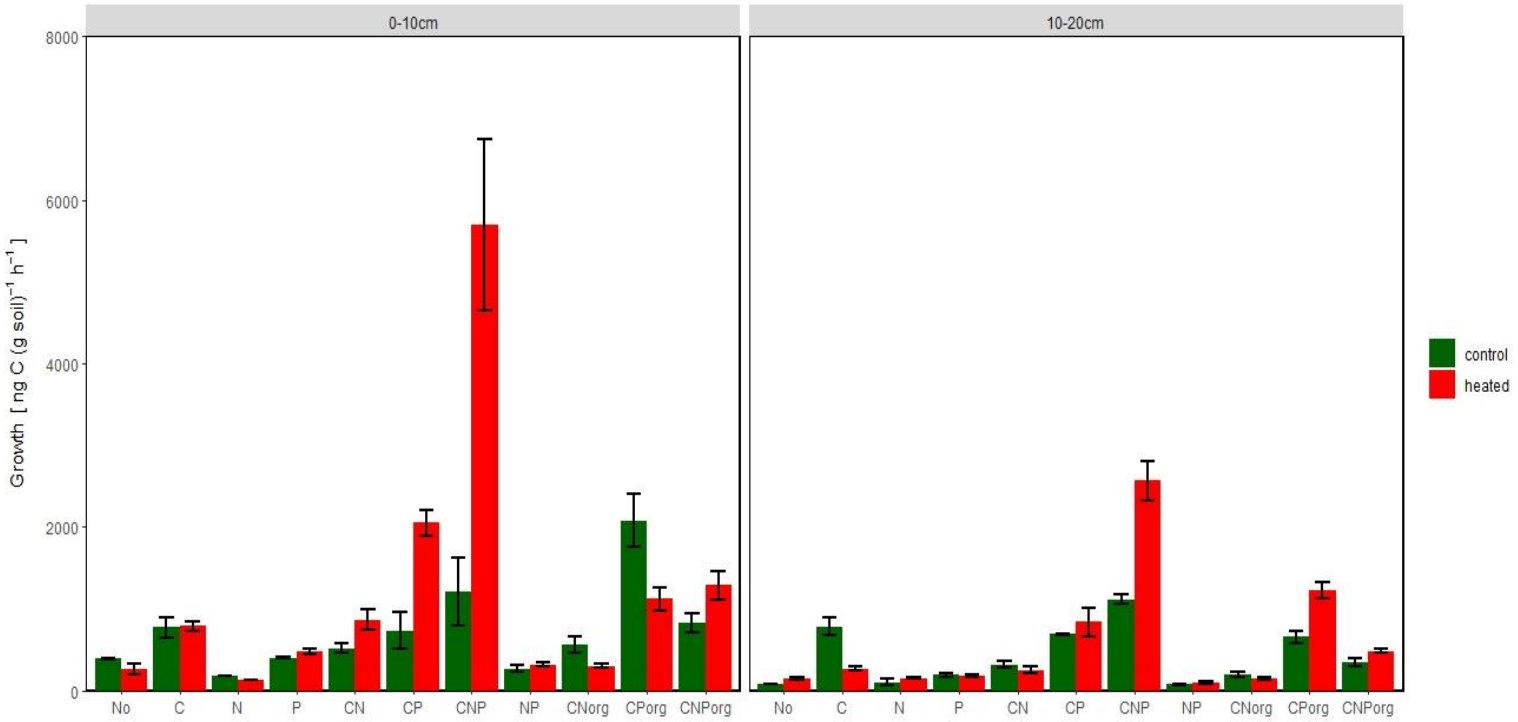
Method for determining microbial growth rate:

^{18}O incorporation rate into DNA

- All substrates are dissolved in 20 atom% $H_2{}^{18}O$
- Atomic ratio of C/N/P in substrates is 6/1/1
- Amount of C added = microbial biomass C (C_{mic})
- DNA quantified by the Picogreen fluorescence assay 24 hrs after incubating soils with substrates
- Growth rate calculated based on a linear relationship between the microbial DNA and the microbial biomass C

Substrate addition	Total addition (g g soil C_{mic}^{-1})		
	C	N	P
No addition control	0	0	0
Glucose	1	0	0
NH_4Cl	0	0.19	0
KH_2PO_4	0	0	0.43
Glucose + NH_4Cl	1	0.19	0
Glucose + KH_2PO_4	1	0	0.43
Glucose + NH_4Cl + KH_2PO_4	1	0.19	0.43
NH_4Cl + KH_2PO_4	0	0.19	0.43
Glucosamine	1	0.19	0
Glucose-6-P	1	0	0.43
Glucosamine-6-P	1	0.19	0.43

Result



- Stronger C-limitation of microbial growth in heated than in control plots in topsoil (0-10 cm), however, this pattern is reversed for subsoil (10-20 cm).
- Even P addition alone stimulated significant growth response in heated topsoil
- Shift from C-only limitation to CP co-limitation after 15 yrs warming.
- Extra growth stimulation by CNP addition

In terms of inorganic and organic amendments:
More rapid microbial growth response was induced by Glc + inN (CN) than glucosamine (orgCN), similar for Glc + inNP (CNP) and glucosamine-6-phosphate (orgCNP), probably due to low active transporters for glucosamine and glucosamine-6-P uptake or little mineralization of these two substances within 24 hrs.

Discussion

Possible explanations for warming-induced CP co-limitation:

- N is supplied rapidly enough through enhanced N mineralization, P supply via weathering and other pathways cannot keep up.
- Enhanced abiotic phosphate immobilization constrained Pi availability in soil

  A parallel experiment based on ^{33}P pool dilution method carried out by Tian et al., demonstrated that warming:

  1) Increased abiotic phosphate immobilization (sorption on surfaces)
  2) decreased gross phosphate mobilization and microbial phosphate uptake
  3) increased microbial phosphatase production

  However, the mechanism underlying enhanced abiotic Pi immobilization is not clear. Further analysis of microbial biomass P, DOP, DIP, TP and minerology data are required.