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Soil microbial growth and carbon-use efficiency: dependence on nitrogen availability, pH and organic matter quality

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Microbial decomposers are responsible for the breakdown of organic matter (OM) and thus regulate soil carbon (C) stocks. During the decomposition of OM, microorganisms can use the assimilated C for biomass production or respire it as CO_2, and the fraction of growth to total assimilation defines the microbial carbon-use efficiency (CUE). As such, CUE has direct consequences for how microbial decomposers affect the balance of C between atmosphere and soil, and is as such a central parameter to constrain in order to represent the global C cycle well in Global Cycling Models (GCMs). Despite its enormous leverage this factor remains critically underexplored. In this study, we determined how the major drivers of soil bacterial and fungal growth rates –soil pH, nitrogen availability, and OM quality – governed the microbial CUE in a field survey combined with a set of factorial microcosm experiments. We sampled temperate forest soils, temperate agricultural soils, and subarctic forest soils, encompassing a wide range of soil pHs (4.0-7.1), nutrient availabilities (10<soil C/N<33), and soil OM qualities (7-fold differences in respiration per SOM). In addition, we subjected each of these soils to microcosm experiments where soil pH (liming), mineral N (50 kg N ha-1), and OM quality (plant litter) were manipulated and the resulting bacterial and fungal growth, respiration, and CUE were monitored over the course of 2 months.

We observed that fungal-to-bacterial growth ratios (F:B) ranged from 0.02 to 0.44 across the studied ecosystems, and that the fungal dominance was higher in soils with lower C:N ratio and higher C-quality. CUE ranged from 0.03 to 0.30, and values clustered most strongly according to site rather than level of soil N. CUE was higher in soil with high C:N ratios and high C-qualities. However, within each land-use type, a high mineral N-content did result in lower F:B and higher resulting CUE. In the microcosm experiments, plant litter addition stimulated the growth of fungi more than bacteria, while increasing soil pH stimulated bacteria more than fungi. Mineral N additions inhibited bacterial growth and stimulated fungal growth. This resulted in microbial CUE estimates resolved in real time that ranged from ca 0.05 to 0.55, and where increased pH and litter both transiently increased values while mineral N supplements decreased values. In conclusion, a higher site soil C-quality coincided with lower F:B and higher CUE across the surveyed sites, while a higher N availability did not. A higher site N availability resulted in higher CUE and lower F:B within each site, while mineral N supplements in the microcosm induced the opposite response, suggesting that site-specific differences associated with fertility such as the effect of plant communities, overrode the influence of mineral N-availability.