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Contrasting effects of organic and mineral nitrogen challenge the N-Mining Hypothesis for soil organic matter priming

Kyle Mason-Jones[a,*], Niklas Schmücker[a], Yakov Kuzyakov[a,b,c]

[a] Department of Agricultural Soil Science, Department of Soil Science of Temperate Ecosystems, University of Goettingen, Büsgenweg 2, 37077, Goettingen, Germany
[b] Agro-Technology Institute, RUDN University, Moscow, Russia
[c] Institute of Environmental Sciences, Kazan Federal University, 420049, Kazan, Russia

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ABSTRACT

Addition of easily available organic substances to soil often increases the CO_2 efflux from pre-existing soil carbon (C). This phenomenon is often explained in terms of the Nitrogen (N)-Mining Hypothesis. According to this proposed – but never conclusively proven – mechanism, increased C availability induces N limitation in microbes, which then access N by degrading soil organic matter (SOM) – a priming effect. This is supported by some experiments demonstrating reduced CO_2 efflux after mineral N addition. However, amino acids cause priming, despite their very low C:N ratios and rapid deamination to mineral N. To explore this contradiction, we applied ^{14}C- and ^{15}N-labelled C and N sources (glucose, alanine and ammonium sulfate) to rigorously test two key predictions of the N-Mining Hypothesis: (i) an amino acid should stimulate much less priming than glucose, and (ii) priming should be similarly suppressed for an amino acid or a stoichiometrically equivalent addition of glucose plus mineral N. Both of these key predictions of the N-Mining Hypothesis failed. Efflux of CO_2 from native C was essentially determined by the type and amount of C added, with alanine stimulating more priming than glucose (16–50% cumulative increase relative to control, versus 0–25%, respectively). Higher C additions caused more priming than low additions. Mineral N reduced native-C-derived CO_2 efflux when added alone or with organic substrates, but this effect was independent of the organic C additions and did not influence C-induced priming. These results were inconsistent with the hypothesized role of N mining in priming. We conclude that the N-Mining Hypothesis, at least in its current form, is not a universal explanation for observed priming phenomena.

Instead, we observed a strong correlation between the rates of priming and the mineralization of the added substrates, especially during the first 8 days. This indicated that priming was best explained by energy-induced synthesis of SOM-degrading exoenzymes, possibly in combination with apparent priming from accelerated turnover of microbial biomass.

1. Introduction

The processes governing soil organic matter (SOM) mineralization are not yet fully understood, despite their considerable importance to C sequestration, greenhouse gas emissions, soil fertility and groundwater protection. Mechanistic explanations often point to interactive effects of carbon (C) and other nutrients, notably nitrogen (N). The N-Mining Hypothesis is a prominent example. According to this hypothesis, N-limited microorganisms mineralize SOM to access the N contained within (Fontaine et al., 2011; Moorhead and Sinsabaugh, 2006). This can elegantly explain why an easily available C input often increases the CO_2 efflux from pre-existing soil C (Kuzyakov, 2010): when supplied with an abundant source of C and energy, microorganisms become N-limited and actively degrade organic materials that they would not degrade to acquire C alone (Garcia-Pausas and Paterson, 2011). Therefore, according to the N-Mining Hypothesis, SOM mineralization is negatively correlated to N availability, and positively correlated to C availability (Fontaine et al., 2011).

A change in SOM mineralization rate in response to relatively moderate treatment is termed a priming effect (PE) (Kuzyakov et al., 2000). Organic substances added to soil will be mineralized and therefore contribute to the total CO_2 efflux, but isotopic labelling (^{13}C or ^{14}C) allows this to be distinguished from CO_2 derived from pre-existing soil C pools. Here we refer to these pools as “native C”, which includes the living soil microbial biomass and non-living SOM at the time of exogenous C addition. Exogenous carbon could increase or

* Corresponding author.
E-mail address: kmasonjones@gmx.de (K. Mason-Jones).

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