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"Non-metabolizable" glucose analogue shines new light on priming mechanisms: Triggering of microbial metabolism

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

[a] Department of Agricultural Soil Science, Georg-August-University of Göttingen, Büsgenweg 2, 37077 Göttingen, Germany
[b] Department of Soil Science of Temperate Ecosystems, Georg-August-University of Göttingen, Büsgenweg 2, 37077 Göttingen, Germany
[c] Institute of Environmental Sciences, Kazan Federal University, 420049 Kazan, Russia

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ABSTRACT

Priming of soil organic matter decomposition has attracted much research interest, yet a conclusive mechanistic explanation of the phenomenon remains elusive. One proposal is that low molecular weight organic substances might "trigger" an acceleration of microbial metabolism. For the first time, we applied a glucose analogue to soil to demonstrate triggering of microbial metabolism, and to estimate its relative contribution to priming. "Non-metabolizable" glucose analogues have been widely used in pure culture studies to mimic glucose, but never in soil biochemistry. We hypothesized that analogue molecules will elicit a metabolic response in microorganisms despite limited catabolism, and thereby confirm the proposed triggering.

The effect of ^{14}C-labeled 3-*O*-methyl-D-glucose (OMG) – a common "non-metabolizable" glucose analogue – on soil organic matter mineralization was compared to that of ^{14}C-labeled D-glucose. OMG was mineralized, but its mineralization was initially impeded and substantially delayed, relative to glucose. OMG caused brief but strong priming in the first 24 h, increasing unlabeled CO_2 efflux by 173%, 89% and 36% above control for additions of 0.49, 2.4 and 4.9 μmol OMG g^{-1} soil, respectively. In contrast, glucose caused low or negative priming on the first day. On the first day after OMG addition, a negative correlation between priming and OMG mineralization indicated that triggering is a valid mechanism of microbial activation during a famine-feast transition, but is short-lived.

Glucose mineralization peaked on the second day for medium and high additions, coinciding with peaks in positive priming. Maximum substrate mineralization also coincided with peaks in priming for medium and high OMG levels, but these occurred 9 and 11 days after addition, respectively. This revealed non-triggering priming mechanisms, which contributed most to priming and were closely coupled to substrate mineralization. By separating energy- and substrate-dependent metabolic processes from triggering processes, the glucose analogue 3-*O*-methyl-D-glucose enabled triggering to be demonstrated, but triggering by glucose occurs without contributing greatly to priming.

1. Introduction

Addition of low molecular weight organic substances (LMWOS) to soil can change the mineralization rates of pre-existing soil organic matter (SOM), a phenomenon termed priming (Kuzyakov, 2010). Priming effects have attracted much research interest, yet a conclusive mechanistic explanation remains elusive (Rousk et al., 2015). In light of the roles that priming plays in the global C cycle and in plant nutrition, a better understanding of its drivers is urgently needed.

Various possible priming mechanisms have been proposed. These have been comprehensively reviewed elsewhere (Blagodatskaya and Kuzyakov, 2008) and are briefly summarized in Table 1.

The "microbial triggering" hypothesis holds that an increased LMWOS availability can be detected by microorganisms. They accelerate their metabolism and energy state in expectation of a "food event", increasing their CO_2 output (Blagodatskaya and Kuzyakov, 2008; De Nobili et al., 2001). Stimulation of short-term priming by very small additions of LMWOS has been explained by triggering (Mondini et al., 2006). Triggering is unique among the

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

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