SEL Research
土壤碳激发效应的时间动态及其对氮添加的响应

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Distinctive mechanisms of soil priming in different stages and its response to nitrogen addition along a temperate forest elevation gradient

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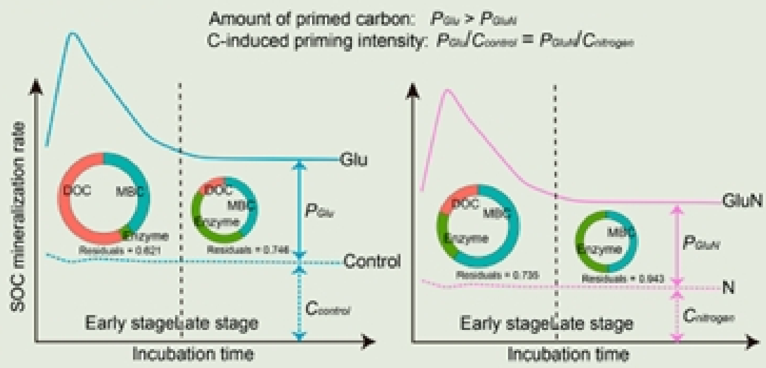
ABSTRACT

• Positive priming peaked in the early stage, and then declined and remained stable.

• Early priming was attributed to the increased MBC content and abiotic mediation.

• Late priming was further attributed to the increased enzyme activities.

• Nitrogen addition had no effect on carbon-induced priming intensity.



Priming of soil organic carbon (SOC) mineralization by fresh carbon inputs plays an important role in terrestrial carbon cycling. Despite the attempts to elucidate the mechanisms of soil priming and its response to nitrogen addition, findings remain discordant or even contradictory. We conducted a 30-day incubation experiment using ^{13}C-labeled glucose and nitrogen addition on 51 soils (belonging to 15 soil profiles along a temperate forest elevation gradient). Results showed that positive priming peaked in the first four days of incubation, and then declined and remained relatively stable. Early-stage priming was positively correlated with the response of soil microbial biomass and SOC-derived dissolved organic carbon. In the late stage, extracellular enzyme activities increased, and their responses were positively correlated with priming intensity. These results suggested that early-stage priming was mainly driven by the adjustment in soil microbial biomass and the abiotic mediation of mineral-protected organic compounds,

本研究采集沿海拔梯度的51份森林土壤样本，开展13C标记葡萄糖和氮添加的30天培养实验，通过土壤可溶性碳氮含量、微生物量、胞外酶酶活性、微生物群落、土壤pH值的响应，解析激发作用的时间动态及其产生机理。结果发现，早期阶段（0~4天）：激发效应强度最高，主要由微生物生物量的增加和矿物保护有机碳的非生物释放驱动。晚期阶段（4~30天）：激发效应趋于稳定，主要受微生物胞外酶活性增强的影响，考虑到富营养型微生物丰度的增加以及后期微生物对氮需求的下降，后期的正激发主要受化学计量分解理论驱动。氮添加虽降低了土壤微生物生物量和酶活性（可能因土壤酸化），但对碳添加引起的激发效应强度无显著影响。本项研究通过时间尺度的精细观测，明确了激发效应的阶段性特征，为理解土壤碳-氮耦合过程提供了重要线索。

新鲜碳输入可引起土壤原有有机碳矿化（SOC）速率的增强或减弱，这一过程称之为激发效应。激发效应在陆地碳循环中具有重要作用，尽管学界已尝试阐明土壤激发效应的作用机制及其对氮添加的响应，但现有研究结论仍存在分歧。

本研究选取秦岭太白山不同海拔和深度的51个土壤，在室内开展为期30天的13C标记葡萄糖和氮

添加的培养实验。培养过程中，监测碳排放速率，以及土壤可溶性有机碳、可溶性全氮、微生物量碳、微生物量氮、胞外酶酶活性、微生物群落、土壤pH值等的变化。通过分析激发强度与上述变量的响应程度的关系，阐明不同阶段激发效应的产生机理及其对氮添加的响应。结果表明，土壤激发效应强度变化显著，在培养前4天达到峰值后逐渐降低，并在后续26天保持相对稳定。葡萄糖添加后，土壤微生物生物量、SOC来源的可溶性有机碳含量增加、qCO2、富营养微生物的相对丰度显著升高，这些指标的响应程度与早期激发强度呈显著正相关。在晚期阶段，除微生物量变化外，胞外酶活性显著增强且与激发强度呈正相关。这表明早期激发效应主要受微生物量的增加和矿物保护有机质的非生物释放驱动，而晚期激发则由胞外酶酶活性增强驱动。氮添加虽抑制了微生物生物量及SOC矿化，但这种抑制效应在有无葡萄糖添加处理间无显著差异，因此不影响碳添加引起的激发强度。

本研究揭示了激发强度的时间动态及其作用机理在时间上的转变，有助于动态理解生态系统碳过程，为全球变化背景下土壤碳循环模型的优化提供新依据。同时，在分析氮素影响时，需区分碳添加的响应和氮添加的响应，以准确评估相关过程。

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专题征稿

城市土壤生态与同一健康

Call for papers: Urban Soil Ecology and One Health

Urban landscapes are complex incubators for emerging public health threats, including the persistence and spread of zoonotic pathogens that jeopardize the integrated health of humans, animals, plants, and environments—a nexus addressed by the One Health framework. Within these ecosystems, soil biodiversity is a keystone component that underpins critical ecosystem functions, yet it persists as one of the least understood elements of urban ecosystems.

Aligned with the World Soil Day 2025 theme, "Healthy soils for healthy cities," this special issue calls for research to address this knowledge gap. We seek submissions that illuminate the distribution patterns and functional contributions of urban soil biota, particularly under pressures from human activity and climate change. We are also interested in studies exploring how harnessing urban soil biodiversity can lead to nature-based solutions for mitigating biodiversity loss, adapting to climate change, and reducing the urban burden of disease. We particularly encourage studies proposing frameworks for embedding soil biodiversity into urban governance and policy to directly enhance One Health outcomes.

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