Unraveling the Molecular Mechanisms Underlying the Microbiome Response to Soil Rewetting

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Soil microbes are highly sensitive to changes in their environment, and rapidly measuring their responses is necessary to fully understand the biological processes. Drought is one of the most common environmental stresses that soil microbiomes experience, and it is important to understand the mechanisms by which the soil microbiome respond to soil dehydration. We used $^{13}$C as a tracer of nutrient fluxes in desiccated soil microbiomes after rewetting to simultaneously measure aerobic respiration and track the metabolic state of the community. Here, we describe a Real Time Mass Spectrometry (RTMS) approach for rapid gas monitoring combined with omics approaches to track $^{13}$C flow through a soil system.

The mechanism(s) behind the burst of rapid mineralization of soil organic matter and increased rate of CO$_2$ release upon rewetting dry soil (termed the 'Birch Effect') are yet to be fully defined. One known mechanism used by microbes to protect against dehydration is the production of intracellular compounds known as osmolytes. We evaluated metabolic mechanisms produced upon rewetting a marginal soil testing the hypothesis that the rapid release of CO$_2$ arises from the microbial processing of putative intracellular osmolytes that build up during desiccation. RTMS allows for the simultaneous, rapid and fine scale (every 2 sec) evaluation and deconvolution of the production and consumption of a number of gasses including $^{12}$CO$_2$, $^{13}$CO$_2$, O$_2$, N$_2$ and H$_2$O. We compared the hydration response (production of CO$_2$ in real time) between the addition of water and $^{13}$C labeled glucose dissolved in water. The initial burst of $^{12}$CO$_2$ followed by a leveling off was identical in both treatments with an additional larger increase in $^{13}$CO$_2$ about 20 minutes later in the $^{13}$C labeled glucose experiment. Examination of the two minutes after the water addition revealed a rapid rate of $^{12}$CO$_2$ (38 sec) and H$_2$O (47 sec) production and slow rate of $^{13}$CO$_2$ (56 sec) production followed by the consumption of O$_2$ (67 sec) and N$_2$ (73 sec). Evaluation of the soil metabolomes at specified time points within 3 hours after wetting revealed the immediate release of sugars from the cells into the extracellular matrix. These results provide evidence for respiration of putative intracellular osmolytes as one driving mechanism of the Birch Effect.