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Reconstruction of food webs in biological soil crusts using metabolomics.

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Biological soil crusts (BSCs) are communities of organisms inhabiting the upper layer of soil in arid environments. BSCs persist in a dessicated dormant state for extended periods of time and experience pulsed periods of activity facilitated by infrequent rainfall. Microcoleus vaginatus, a non-diazotrophic filamentous cyanobacterium, is the key primary producer in BSCs in the Colorado Plateau and is an early pioneer in colonizing arid environments. Over decades, BSCs proceed through developmental stages with increasing complexity of constituent microorganisms and macroscopic properties. Metabolic interactions among BSC microorganisms probably play a key role in determining the community dynamics and cycling of carbon and nitrogen. However, these metabolic interactions have not been studied systematically. Towards this goal, exometabolomic analysis was performed using liquid chromatography coupled to tandem mass spectrometry on biological soil crust pore water and spent media of key soil bacterial isolates. Comparison of spent vs. fresh media was used to determine uptake or release of metabolites by specific microbes. To link pore water experiments with isolate studies, metabolite extracts of authentic soil were used as supplements for isolate exometabolomic profiling. Our soil metabolomics methods detected hundreds of metabolites from soils including many novel compounds. Overall, Microcoleus vaginatus was found to release and utilize a broad range of metabolites. Many of these metabolites were also taken up by heterotrophs but there were surprisingly few metabolites uptaken by all isolates. This points to a competition for a small set of central metabolites and specialization of individual heterotrophs towards a diverse pool of available organic nutrients. Overall, these data suggest that understanding the substrate specialization of biological soil crust bacteria can help link community structure to nutrient cycling.