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Photoautotrophic organisms control microbial abundance, diversity, and physiology in biological soil crusts

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In dryland systems all over the world vascular vegetation is typically quite sparse or even absent, whereas the ground surface is not bare, but largely covered by biological soil crusts (referred to as biocrusts hereafter). These biocrust communities are composed of poikilohydric organisms, i.e., photoautotrophic cyanobacteria, lichens, and mosses growing together with heterotrophic fungi, bacteria, and archaea in varying proportions. Based on the dominating photoautotrophic organism, different types, i.e., cyanobacteria-, lichen-, and moss-dominated biocrusts are distinguished, which also represent different successional stages of biocrusts. Biocrusts fulfill highly important ecosystem services being relevant in global carbon and nitrogen cycling.

The intention of the present study was to investigate the relevance of the dominating photoautotrophic organism for biocrust microbial composition and physiology. Thus, we first conducted high-throughput 16S rRNA gene and fungal internal transcribed spacer (ITS) region sequencing of the different crust types and bare soil to analyze the microbial composition. In a second step we analyzed the CO_2 gas exchange rates and reactive trace gas emissions to obtain information on the physiological properties of the different biocrust types based on the varying microbial composition.

According to our results, gene copy numbers of bacteria and fungi increased from bare soil to biocrusts and along biocrust succession. In particular, fungi were more relevant towards later successional stages. Bacterial communities differed significantly between biocrust types: generalist bacteria predominated in earlier successional stages, whereas more specialized lineages became increasingly important in later stages of biocrust succession. CO_2 gas exchange measurements revealed characteristic adaptations to the environmental factors water, light, and temperature for the different types of biocrusts. Respiration rates of the heterotrophic fraction of the biocrust (with the photosynthesizers being removed) were high for moss-dominated biocrusts, indicating large microbial activity, whereas those for cyanobacteria- and lichen-dominated biocrusts were negligible. Different types of biocrusts also showed distinct and characteristic nitric oxide (NO) and nitrous acid (HONO) emission patterns during wetting and drying cycles. Thus, our study suggests that the dominating photoautotrophic organisms have an impact on habitat characteristics, facilitating microbial communities, which themselves influence the physiological functioning of biocrusts and hence their impact on local and global nutrient cycles.