Microbial Architects of the Cold Deserts: A Comprehensive Research of Biological Soil Crusts in the High-Altitudinal Cold Deserts of the Western Himalayas

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Abstract

Our research has focused on Biological Soil Crusts (BSCs) in the Western Himalayas, specifically in Tibetan Plateau and Karakoram (Ladakh, India) along the elevation gradient spanning a range of 4300–6000 m a.s.l. where habitats like cold deserts, steppes, alpine and subnival vegetation, as well as primary successional stages behind retreating glaciers are present. These regions are characterised by extensive development of BSCs, with cyanobacteria as the dominant component. BSCs are of great significance for the sustainability and development of ecosystems of arid regions worldwide. Their activity is limited to brief periods when precipitation or dew hydrates microbial cells, enabling metabolic activity. Despite the crucial role played by these phototrophic microbial communities in arid and semi-arid ecosystems worldwide, remote mountain regions like the Tibetian Tibetan Plateau and Karakoram have received limited attention in this regard. More than 15 years long research allowed us to determine several critical aspects of BSCs' activity and performance:

1. We conducted laboratory and in-situ experiments Fig. 1 to assess the potential photosynthetic and heterotrophic activity of BSCs from high-altitude cold deserts. The experiments involved measuring the production and consumption of CO_2 and O_2 by BSCs under various temperature and moisture conditions, as well as light intensity. By manipulating these factors, we could differentiate the activities of heterotrophs and autotrophs within the BSCs. The results of these experiments were then analysed in the context of soil nutrient stoichiometry, phylogenetic structure, and microbial community biomass. Using these data, we developed a mechanistic mathematical model to predict the overall metabolic activity of BSCs in response to the major climatic drivers: temperature and moisture. This knowledge could help us to predict the reaction of BSC to climatic changes and reveal if the arid areas in Western Himalayas will act as CO_2 sources or sink.

2. We further investigated the composition and content of pigments in microbial soil communities across various habitats along the elevation gradient in the Tibetan Plateau (Rehakova and Capkova 2019). Soil microbes have evolved complex metabolic strategies, such as producing photoprotective and photosynthetic pigments, to survive the environmental stress caused by high UV radiation, fluctuating temperatures, and drought.
3. We also examined the effects of environmental factors such as altitude, mountain range, and soil physico-chemical parameters on the composition and biovolume of phototrophs which dominate the BSc in the studied region (Řeháková 2011, Janatková and Řeháková 2013). This was accomplished through multivariate redundancy analysis and variance partitioning. Interestingly, the phylogenetic diversity and morphotypes' composition were similar between the Karakoram and Tibetan Plateau (Čapková 2015). Our investigation represents the first recorded assessment of the phylogenetic diversity of cyanobacterial communities within biological soil crusts in the Western Himalayas, specifically at altitudes exceeding 5000 m.

Keywords

in-situ experiments, extreme environment, Tibetan Plateau, East Karakoram, ecophysiology of soil microbes, carbon sink/source, cyanobacteria

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Presented at

as poster in Part 4: Emerging Tools & Areas of Scientific Inquiry

Conflicts of interest

The authors have declared that no competing interests exist.

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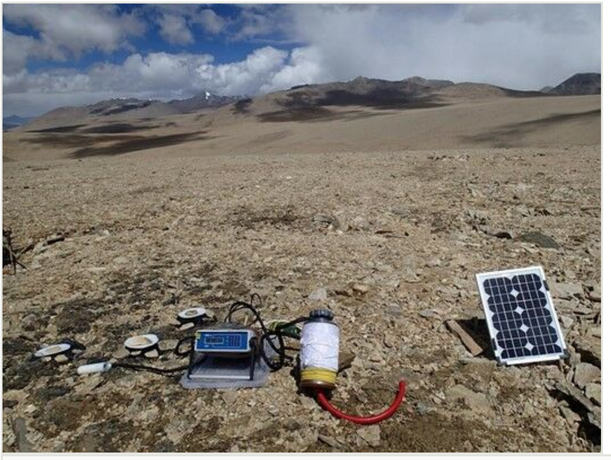

Figure 1.

Measuring the metabolic activity of biological soil crusts in-situ in 6000 m asl. Tibetan Plateau, Ladakh, India.