Seasonal Relationships of Alpine Plants and Microbes through a Stoichiometric and Enzymatic Lens

Adam T Ruka[‡,§], Johannes Scheichhart[|,§], Jiří Doležal[‡,§], Kateřina Čapková[‡], Travis B Meador[|,§], Roey Angel[|], Rosa Paulina Calvillo-Medina[|], Zuzana Chlumská[‡], Nadine Praeg[¶], Paul Illmer[¶], Klára Řeháková[‡]

‡ Institute of Botany, Czech Academy of Sciences, Třeboň, Czech Republic
§ Faculty of Science, University of South Bohemia, České Budějovice, Czech Republic
| Institute of Soil Biology and Biogeochemistry, Biology Centre, Czech Academy of Sciences, České Budějovice, Czech Republic
¶ Department of Microbiology, University of Innsbruck, Innsbruck, Austria

Corresponding author: Adam T Ruka (adamruka@hotmail.com)

Abstract

Alpine biomes experience harsh environmental conditions and short growing seasons, which necessitate interspecific and intraspecific interactions to ensure the stability of diversity and ecosystem multifunctionality. The relationship between plants and microbes in this environment is equally dynamic, with seasonal pulses of nutrients and the phenology of plants creating specific "hot moments" of biogeochemical activity. As a crucial zone of interaction between plant roots and microbial communities, the rhizosphere serves as a "hot spot" of biogeochemical cycling where the mineralization of nutrients, such as carbon, nitrogen, and phosphorus, allows for the transfer of nutrients between trophic levels. However, the nature of these interactions depends on edaphic and climatic conditions, potentially leading to cooperation or competition to meet the stoichiometric demands of organisms.

Elevation gradients within alpine ecosystems provide dramatic shifts in temperature, precipitation, and soil development that allow for the study of these interactions over short geographical distances. In conjunction with seasonal sampling, this approach can provide a wide environmental context to observe the relationship between specific plants and microbial communities. By investigating the C/N ratios of plants, microbes, and soil, as well as microbial enzymatic potential, we can infer nutrient limitations, temporal niche partitioning, and biological responses to abiotic conditions.

Within the Austrian Alps, we studied a selection of herbaceous plants and their associated microbial communities across an elevation gradient spanning 2200-2800 m (Fig. 1). The primary aims of the study were to assess the seasonal changes in C/N stoichiometry from both trophic levels, microbial enzymatic potential, and rhizosphere

diversity of bacterial and fungal communities. To fulfill these aims, four locations were selected based on the two present biomes (alpine meadow and sub-nival zone) and the transition between them. Four to five plant species were collected during each season in 2023, including the often-neglected snow-covered winter season, along with rhizosphere and bulk soil for microbial biomass measurements and soil chemistry. Plant leaf tissue samples were analyzed using Isotope-ratio mass spectrometry for plant C/N ratios, while soil and microbial C/N ratios were calculated using chloroform fumigation extraction. Microbial enzymatic potential was assessed using hydrolase enzymatic assays for five fluorophore-labeled substrates. 16S-rRNA and 18S-rRNA genes were sequenced using an Illumina MiSeq platform from the fine roots of collected plant individuals to quantify the relative abundances of bacterial and fungal taxa.

The findings of our study indicate that the higher microbial biomass (Cmic) in alpine meadow locations leads to increased enzymatic activity compared to sub-nival zones. However, specific plant species were found to enhance microbial biomass and enzymatic potential in different seasons, suggesting that plants promote microbial interaction and biogeochemical cycling during different seasons as a form of temporal niche partitioning. Most plant species demonstrated an increase in C/N ratios throughout the season, sometimes
increasing by more than 200%. However, two Poa spp. showed the highest C/N ratios during the summer, which further correlated with higher microbial C/N ratios.

By observing changes in stoichiometric ratios of organisms that interact and share nutrients, we propose that these relationships vary between host plants depending on their temporal niche and abiotic factors (soil and environmental conditions). Furthermore, the positive or negative correlation of plant and microbial C/N ratios may indicate the relative cooperation or competition between trophic levels.

Keywords

Bacteria, Fungi, Biogeochemical, Carbon, Nitrogen, Subnival, Rhizosphere, Deglaciation

Presenting author

Adam Taylor Ruka

Presented at

Oral Presentation within the Soils and Sediments or Glaciers, ice sheets, and permafrostat themes of ISEB-ISSM 2023

Conflicts of interest

The authors have declared that no competing interests exist.

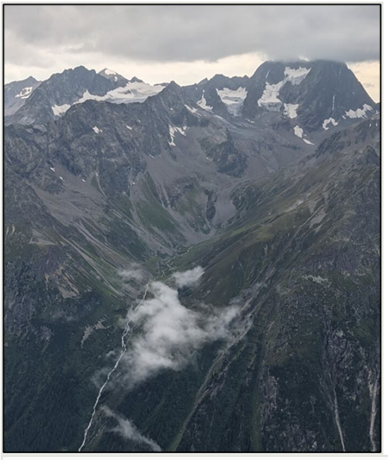

Figure 1.

View of the studied elevation gradient in the Austrian Alps, including alpine meadows at the lower half of the valley and a subnival zone in recently deglaciated terrain.