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Influencing Factors and Consequences: The Effect of Root System on Microbial Community Dynamics under Soil Warming

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The paper titled "Soil warming increases the number of growing bacterial taxa but not their growth rates" was published in the journal *Science Advances* on February 23, 2024, by authors Metze D., Schnecker J., de Charlan C.L.N., Bhattarai B., Verbruggen E., Ostonen I., Janssens I.A., Sigurdsson B.D., Hausmann B., Kaiser C., and Richter A., are from institutions such as the Center for Microbiology and Environmental Systems Science at the University of Vienna, Austria, the Clinical Microbiology Department of the Experimental Medicine Department at the Medical University of Vienna, Austria, and the International Institute for Applied Systems Analysis in Larsenburg, Austria. The study investigated the effects of long-term soil warming on soil bacterial and archaeal communities in subarctic meadows through field experiments and quantitative stable isotope probe (qSIP) technology. The study found that although soil warming led to more bacterial species participating in growth, it did not significantly increase their average growth rate. This study provides new insights into the response mechanisms of soil microorganisms in the context of global warming.

1 Interpretation of Experimental Data

The experiment mainly evaluates the growth dynamics of microbial communities by comparing the soil nucleic acid 18O labeling under different temperature treatments (control group and warming 6°C group). The key results include: significant losses of soil organic carbon and nitrogen, which are correlated with an increase in the growth rate of microbial communities; The warming treatment significantly increased the types of active bacteria, but the average growth rate of these bacteria did not increase.

The study investigated the effects of root system presence and heating conditions on microbial growth by setting up different experimental treatments in a grassland in Iceland that has experienced natural warming from geothermal activity for over 50 years. The experimental results showed that under the condition of increasing temperature by 6°C, the soil carbon content decreased (Figure 1B), while the relative microbial community growth increased (Figure 1C). This indicates that warming may alter soil carbon cycling by affecting microbial activity, which in turn may affect soil carbon storage capacity. In addition, by using grids with different apertures to restrict or allow root growth, this study also attempts to analyze the potential effects of roots on microbial activity and soil carbon cycling.

Figure 6 shows the activity levels of the top 15 microbial families based on the absorption ratio of 18O isotopes in both root and non root treatments under normal temperature and warming conditions. The heatmap reflects the contribution of each family to the overall microbial community growth, which is calculated based on the relative abundance and growth rate of the growing groups. Especially in rooted treatments, such as the Chitinophagaceae family, high growth contributions were observed under both temperature conditions, and there were significant differences compared to rootless treatments. This indicates that the presence of roots may promote the activity and growth of certain specific microbial families, which is particularly significant under warming conditions. In addition, the bubble chart displays the cumulative growth of all displayed families, providing an intuitive comparison of total growth.

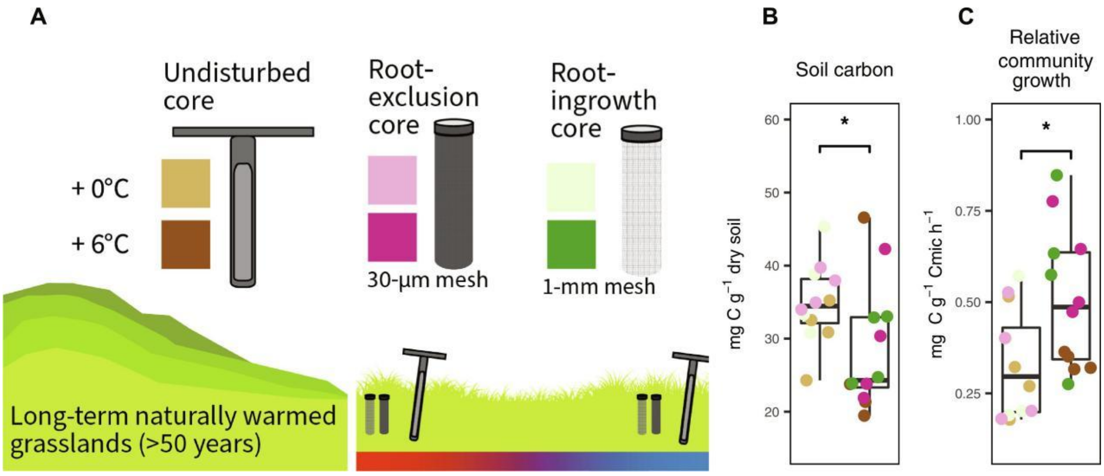

Figure 1 Experimental design, soil carbon, and relative microbial community growth

Note: (A) Soil samples were taken from four replicated temperature gradients (n = 4 biological replicates) in a (Sub)Arctic grassland in Iceland. This grassland experienced at least 50 years of soil warming established by natural geothermal activity. Root-ingrowth and root-exclusion cores were installed in situ for 10 months (October 2019 to August 2020) at two temperature levels (ambient temperatures and +6°C above ambient temperatures). We aimed to investigate how root presence or absence affects microbial growth under warmed conditions. While extracting the in situ installed cores, we also took a fresh soil core (hereafter, undisturbed core) to examine warming effects without the disturbances associated with core installation (e.g., soil extraction, mixing, and root/stone removal). Squares depict treatment colors used for graphs. (B) Concentrations of soil carbon decreased with warming (t = 2.1, df = 18.3, *P = 0.049, n = 12), while (C) relative microbial community growth (mass-specific) increased (t = −2.5, df = 20.7, *P = 0.019, n = 12). The median is represented by the center line of the box, while the upper and lower quartiles are indicated by the box limits. The whiskers represent 1.5 times the interquartile range; any outliers are shown as separate points. We used two-sided Student's t tests to infer differences between warming levels

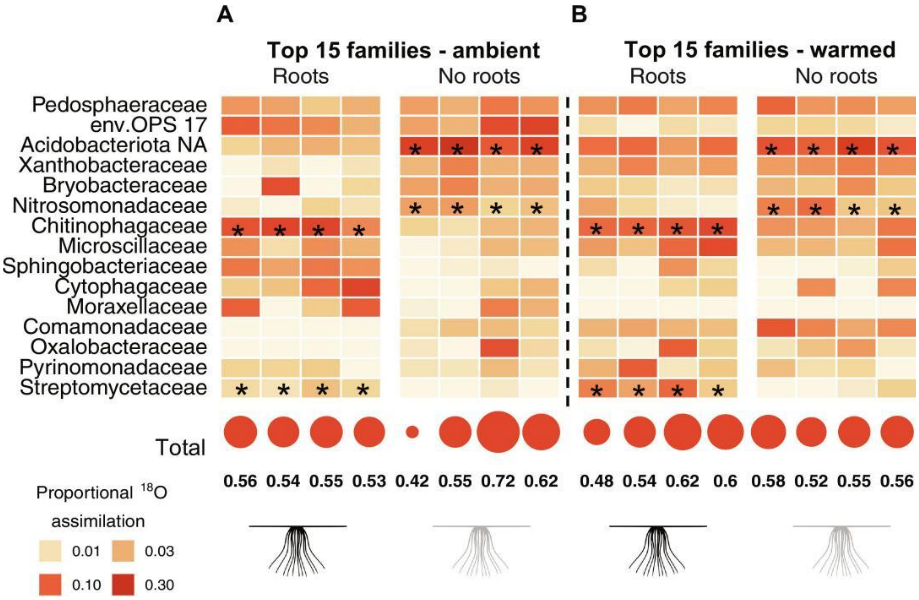

Figure 6 Chitinophagaceae show a higher contribution to the total community's growth in the presence of roots

Note: Heatmap showing the top 15 families based on their proportional 18O assimilation across root-ingrowth and root-exclusion cores at ambient (A) and long-term warmed conditions (B). Individual boxes represent replicates per treatment (n = 4 biological replicates). Proportional 18O assimilation ranges from 0 to 1 and estimates how much a single taxon contributes to the community's overall growth. Hence, it can also be considered as the proportion of bacterial growth an ASV is responsible for. It was calculated using recomputed relative abundances of only growing taxa (sum: relative abundancesgrowing taxa = 1) and their RGRs. ASVs had to be active in at least two samples if detected as growing in a treatment. Proportional 18O assimilation was then agglomerated at the family level and visualized for the top 15 families. If family identity could not be assigned (NA), then phylum names were provided. Bubbles below each replicate box show the cumulative growth summarized over all displayed families. Asterisks "*" (Acidobacteriota NA: P = 0.002,Nitrosomonadaceae: P = 0.044, Chitinophagaceae: P = 0.004, Streptomycetaceae: P = 0.016) represent significant differences between root-ingrowth and root-exclusion cores agglomerated over both temperature regimes based on Wilcoxon rank tests using false detection rate correction for multiple comparisons (n = 4)

2 Insight of Research Findings

The results of this study indicate that the warming effect has a complex impact at the microbial level, not just simply accelerating microbial metabolic activity. More active bacterial species may participate in ecological processes by responding to environmental changes through diverse ecological adaptation strategies, rather than simply increasing growth rates.

3 Evaluation of the Research

The study utilized advanced isotope probe technology to accurately evaluate the growth response of microorganisms at the population level, which is an important advancement in evaluating the response of soil microorganisms to environmental changes. However, research also has certain limitations, such as the geographical and climatic specificity of the experiment, which may affect the universality of the results.

4 Concluding Remarks

Although warming promoted the participation of more bacteria, the average growth rate did not increase, indicating that microbial adaptation to long-term soil warming may involve complex physiological and ecological mechanisms. These findings are of great significance for predicting the impact of soil carbon cycling under global warming.

5 Access the Full Text

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