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# HUMAN & BIOTECHNOLOGY

Fields of Expertise TU Graz

**Gabriele Berg, Human & Biotechnology**

Source: Lunghammer – TU Graz

**The new semester began with change and continuity.** TU Graz is now headed by a new Rectorate team with a new Rector in the person of Horst Bischof. Our FoE executive team worked successfully with him as Vice Rector for Research for many years, for which we would like to express our sincere thanks. At the same time, we are looking forward to working with Andrea Höglinger, who brings a fresh wind from Vienna.

The semester also kicked off with the TU Graz science day Science for Future 2023 – New Worlds in Production. Our FoE organised an afternoon session on "Bio-based products and production", which was very well attended. Presentations from various working groups of our FoE showed that bio-based products have great potential for achieving climate targets. Thanks again to all the young scientists who presented their exciting topics.

We received some good news on the subject of bio-based products at the start of the semester. A new funding period has been approved for Austria's "oldest" competence centre, ACIB (https://acib.at). In its role as an international centre of excellence in the field of industrial biotechnology, ACIB staff have worked on important issues of our time, including the climate crisis, the transition from fossil fuels to renewable resources, the preservation of ecosystems by avoiding harmful waste and ensuring sufficient food to feed the world. Finally, it should be mentioned that after being awarded to Sonja Thaler in 2022, the Stefan Schuy Prize went to TU Graz again this year. The 2023 winner is Hannah Pulferer from the Institute of Neural Engineering. The purpose of the prize is to promote scientific work of excellence in the field of biomedical engineering and is awarded by the Austrian Society for Biomedical Engineering (ÖGBMT). Our congratulations go out to her.

Change and continuity also ensure research. So we look forward to working together in our FoE and invite you once again to join us in shaping it. A new executive team will also be starting at the FoE in January.

We hope you enjoy reading our new issue of the research magazine.

**Samuel Bickel**

**is s a university assistant at the Institute of Environmental Biotechnology.**

Source: Privat

**Samuel Bickel**

# Soil Microbiome Diversity for Biotechnology

Soils harbor rich and complex microbial communities, offering valuable genomic and metabolic diversity. Harnessing their functional potential requires understanding of the interplay between microorganisms and their habitats. Managing soil microbiome diversity for biotechnological applications can improve agriculture, bioremediation, and the formulation of novel bioproducts.

Soil microbiomes are incredibly important for providing soil functions. They host diverse microbiota such as bacteria, fungi, viruses, and other microscopic organisms that interact with each other and their environment. These microorganisms fulfill key roles for the structure of soil, nutrient cycling, fertility, and pollutant degradation that are essential for plant and human health.

## GLOBAL BIOGEOGRAPHY

Despite the small size of microorganisms and their global dispersal, they are not randomly distributed in space. For example, the diversity of soil bacteria shows distinct spatial patterns across terrestrial biomes driven by environmental variables. Unlike plants, which are most diverse in the tropics, the number of bacterial taxa is highest where soil aqueous microhabitats

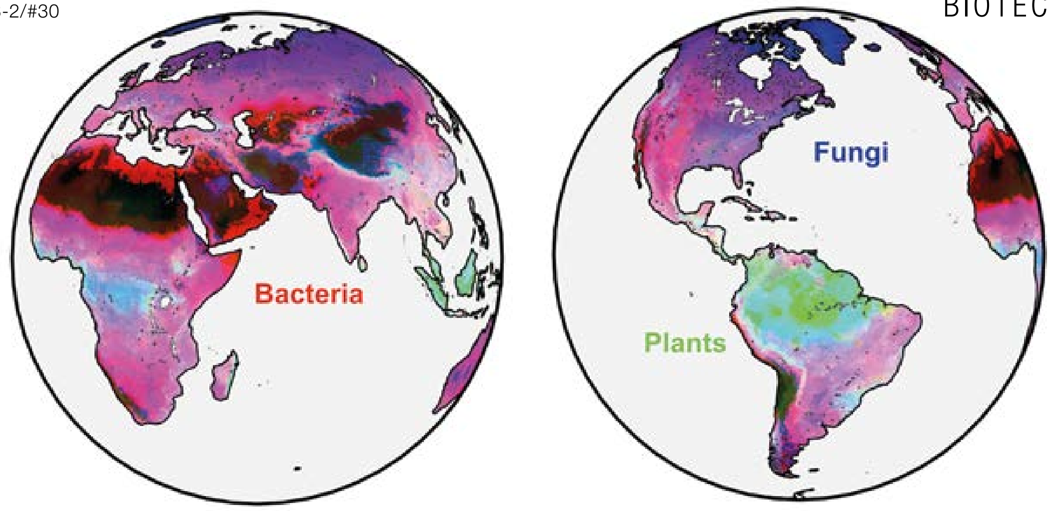


**Figure 1: Estimated global distribution of bacterial, fungal, and plant diversity.**

Source: Samuel Bickel / Institute of Environmental Biotechnology

are numerous, and resources are plentiful. [1] Based on soil's carbon input, water content, and pH, the regions with the highest number of bacterial taxa are found in climatic transition zones. This phenomenon can be in part explained theoretically using concepts from percolation theory linking average soil water content to the number of water clusters in porous media, thus mapping the number of microhabitats and diversity [1].

## DYNAMICS OF BIODIVERSITY

Soil microbiomes are crucial for agriculture and sustainability. Yet, our understanding of the belowground dynamics is limited. The high temporal and spatial variability challenge statistical inferences and require careful planning of soil sampling strategies. Furthermore, the various interactions including arthropods, earthworms, nematodes, and microbiota, call for a holistic assessment of the soil microbiome. In the framework of the Horizon 2020 Excalibur project (excaliburh2020.eu, Grant agreement ID: 817946), we are currently investigating soil biodiversity dynamics in response to microbial inoculants and soil amendments for horticultural production of apple, strawberry, and tomato. By monitoring soil biodiversity dynamics, the project aim is to develop guidelines for farmers and producers to apply novel soil inoculants. The ongoing studies indicate how soil treatment with bacterial and fungal inoculants can shift microbiomes and how its management may shape dynamic interactions among the diverse soil organisms.

**Figure 2: Soil aggregate from an organic apple orchard in Styria with earthworm burrows inhabited by ants. The agar plate shows isolated bacterial colonies extracted from the soil.**

Source: Samuel Bickel / Institute of Environmental Biotechnology

## NICHES FOR BIOCONTROL

The intricate interplay between microorganisms and their physical environment in soil involves chemical, physiological, and ecological processes. Some microbes may break down complex chemical compounds using extracellular enzymes, while others consume simpler forms that can be readily absorbed by plants and other organisms. Such nutrient (re-)cycling processes are essential for maintaining the food webs of agroecosystems, which support plant health and crop production. For example, entomopathogenic fungi are natural antagonists of insects >

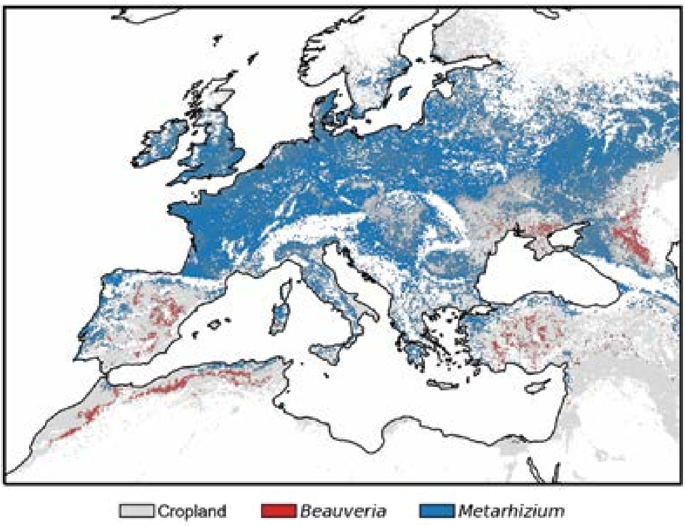


**Figure 3: Biocontrol potential of two fungal genera (Beauveria and Metarhizium) used as insecticides.**

Source: Samuel Bickel / Institute of Environmental Biotechnology that are commercially used for the biological control of pests. However, the efficacy of such biocontrol agents depends on environmental factors shaping their ecological niches. Here, machine learning models can be used for integrating metagenomic and environmental data to classify cropland regions that are suitable for their biocontrol application and guide discovery of new locally adapted biocontrol strains.

## MICROSCALE INTERACTIONS

While fungal hyphae can access soil across many meters, the ranges of soil bacteria are likely much shorter. Most soil bacteria are sessile and often embedded in a self-produced polymer matrix. Due to their micrometric size, the immediate neighborhood of bacterial cells is limited to a few millimeters in the bulk soil. They are scattered on soil pore surfaces in cell clusters of 10 to 10,000 cells with the exception of a few "megacities" near plant roots. The interaction ranges depend on aqueous habitat connectivity and, thus, on climate and soil characteristics [2]. For example, the diffusive exchange of metabolites is restricted by the tortuous water-filled pore space (for gaseous compounds, the connected air-filled pores). Therefore, it is important to study microbiota at the scale relevant to their life.

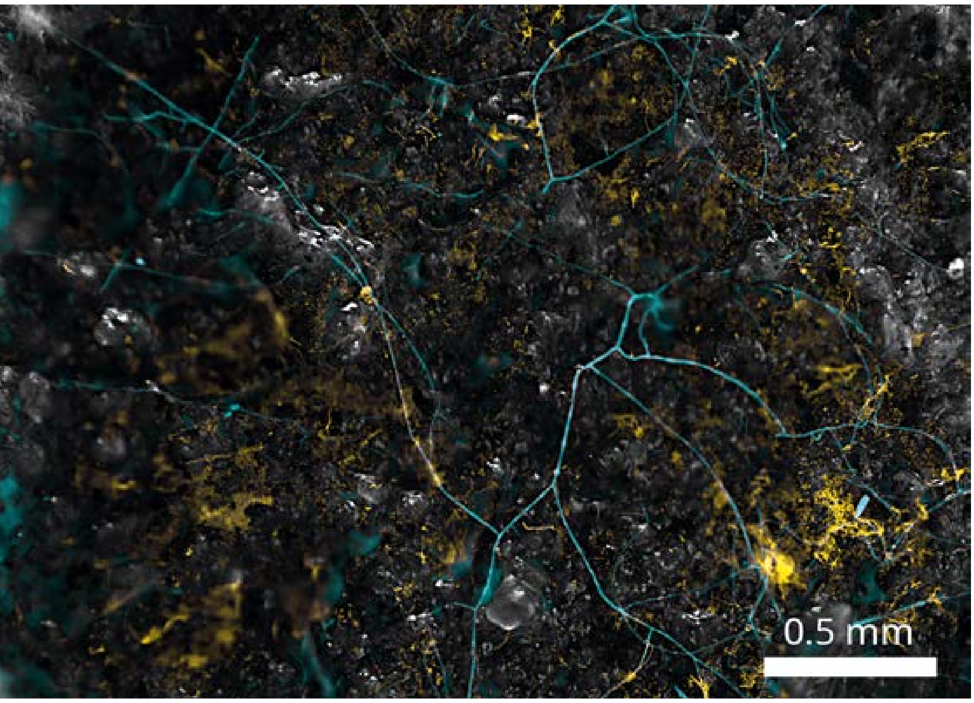


**Figure 4: Fungal hyphae (cyan) spanning across bacterial cell clusters (yellow) on a hydrated soil surface.**

Source: Samuel Bickel, Jingyu Wang / ETH Zurich

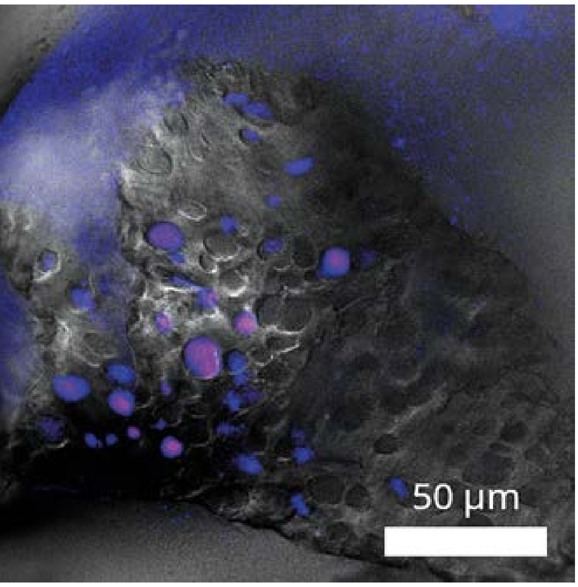


**Figure 5: Bacterial colonies (blue) with damaged cells (magenta) in a dried alginate bead.**

Source: Samuel Bickel, Jingyu Wang / ETH Zurich

## POTENTIAL FOR BIOTECHNOLOGY

One approach to investigate the interactions at small scales is the encapsulation of bacteria and fungi in polymer beads, which can be studied using microscopy. This technology allows fine-tuned control over boundary conditions, population sizes and spatial distributions to investigate ecological interactions for their use in biotechnology. Plant growth promoting bacteria encapsulated in alginate beads are used as seed coatings and soil amendments. Soil microbiome research will uncover novel biotechnological applications that have the potential to mitigate effects of biodiversity loss caused by anthropogenic pollution. A recent estimation by Pavlopoulus et al. revealed that soil microbiomes harbor more than 60,000 novel metagenome protein families [3] providing a vast resource for bioprospecting. The microbiome is considered a "game changer" for agriculture and can be leveraged to develop sustainable solutions for soil remediation and microbe-mediated crop responses to climate stress [4].

## REFERENCES


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