WHAT DOES THE MICROBIOME CONTRIBUTE TO SOIL FERTILITY?

In the context of increasing weather extremes and limited options for the use of fertilisers and plant protection products, a balanced soil microbiome and the microbial promotion of plant stress tolerance are becoming increasingly important. It is essential to better understand the complex interaction of microorganisms and to promote it in a targeted manner. Prof. Dr. Christel Baum from the University of Rostock provides expert scientific insights on this topic.

Key roles in nutrient cycles

Microorganisms support plants in their nutrient uptake, immune defence and stress management. In addition to abiotic, physical and chemical processes, the soil microbiome also plays a key role in soil formation (the formation and development of soils from consolidated or unconsolidated parent material) and thus makes a decisive contribution to maintaining soil fertility.

The soil microbiome fulfils several key functions in the nutrient cycles of soil and plants:

- **Decomposers:** Soil organisms break down organic matter such as crop residues and make the nutrients bound within them available to plants.

- **Symbionts:** Soil organisms live in close association with plant roots, which improves nutrient uptake (e.g. phosphorus or nitrogen) and makes plants more resilient to drought stress or other stresses.

- **Pathogens:** Certain microorganisms can also cause plant diseases, thereby negatively affecting growth and yield.

Furthermore, the microbiome influences carbon sequestration in the soil, as well as the associated release of greenhouse gases and the breakdown of pollutants and pesticide residues.

Soil life on and within the field is largely determined by the site and the farming practices employed. The quantity and quality of the nutrients available to the soil microbiome depend on the main crops grown and the overall crop rotation. The activity of soil organisms can be specifically controlled through the selection and sequence of crops, as well as the composition of plant stands – for example, in cover crop mixtures. This is achieved directly through the supply of nutrients (for example, via organic fertilisation) to the microorganisms and indirectly through changes in soil temperature and soil moisture, which are caused, for example, by shading and the plants’ water consumption.

The microbiome as a buffer against stress

With increasing extreme weather events, such as drought stress or waterlogging, coupled with a reduction in the use of fertilisers and plant protection products, the importance of microbial support for plant stress tolerance is coming into focus.

Over the course of evolution, the soil microbiome has developed a high degree of resilience to stress. Many soil organisms, particularly fungi, can survive adverse conditions by forming special survival structures with very low metabolic activity, such as chlamydospores or sclerotia with thickened cell walls.

What is the soil microbiome?

The soil microbiome refers to the totality of all microorganisms living in the soil, as well as their interactions with one another and with the environment. These include, in particular:

- bacteria,
- fungi (e.g. mycorrhizal fungi),
- archaea, protozoa,
- viruses.

These microorganisms form a complex ecological network that fulfils key functions in the soil.

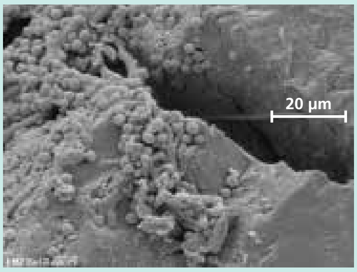

Fig. 1: SEM image of a soil aggregate (scale bar in the bottom right of the photo = 20 µm). This reveals all the life forms living in the soil!

At the same time, part of the soil microbiome helps to improve the stress resistance of crops. To make better use of this potential, both the proportion of active microorganisms in the soil and the diversity of soil life should be specifically promoted – tailored to the respective site.

Fig. 2: The structure, extent and quality of plant root systems play a decisive role in supplying the soil microbiome with nutrients.

» Even if nothing is visible on the surface, the soil is bursting with life! «

Fig. 3: A closer look beneath the surface reveals the complex ecological network of microorganisms.

Importance of microbial biomass

Microbial biomass provides an important nutrient pool, helping to prevent the leaching of phosphates and nitrates. High microbial diversity ensures stable functionality in material cycles. Microbial soil life is particularly promoted by the supply of readily available nutrients, such as those provided by root exudates containing readily available sugars and amino acids. Root exudates also continuously supply nutrients to the root zone (rhizosphere) throughout the entire plant growth cycle. In this way, root exudates and fine root litter create hotspots of microbial life in the soil. Another hotspot of microbial life is the earthworm burrows, with their lining of slime and faeces. Earthworms, too, depend on both the plant population and the soil microbiome for their nutrient supply.

The root system as an interface

As the soil microbiome is largely immobile, it is essential that the crop's root system makes the best possible use of the soil volume. In particular, the close connection between the nutrient-rich topsoil and the subsoil plays a key role here. In terms of structure, quantity and quality, the root systems of plant stands are the most important suppliers of nutrients to the soil microbiome. At the same time, they create biogenic pores that are favoured as habitats not only by the roots of the subsequent crop but also by soil organisms. Diversity in the quality of the root system enables diversity in the physiologically active soil microbiome and, with this, the most effective soil-based suppression of diseases and pests.

Plant diversity for performance

Species-rich plant communities, e.g. in cover crop mixtures, increase the diversity of physiologically active soil microorganisms. The reason for this is that each plant species and variety specifically activates different microbial communities within the soil microbiome. This leads to the greatest possible efficiency of nutrient cycles through a diverse profile of soil enzymes acting as biocatalysts and of secondary metabolites in the organic soil matter. Soil organic matter with a high proportion of diverse microbial necromass (dead biomass) is of high quality and promotes sustainable carbon sequestration in the soil. Soil enzymes promote straw decomposition as well as nutrient mobilisation and the breakdown of pesticide residues.

As the majority of the soil microbiome acts primarily as decomposers, it plays a central role in the soil's nutrient cycles. This decomposition activity creates competition with soil-borne pathogens, as it either deprives them of their means of survival or causes their food sources in the soil to be broken down more quickly. As a result, many pathogens are less able to survive in the soil until the next host plant.

Soil-borne pathogens contribute to so-called 'soil fatigue', particularly in legume cultivation. A soil microbiome with high diversity and high biological activity can counteract this effect and thus makes an important contribution to soil health.

Conclusion

An active and diverse soil microbiome is a cornerstone of soil fertility and soil health. It stabilises nutrient cycles, improves nutrient efficiency, increases resilience to stress factors and contributes to the sustainable use of agricultural soils. The soil microbiome can be specifically supported through crop rotation planning, plant diversity and the promotion of root growth – a benefit for sustainable crop rotations.

The case studies by DSV consultants Andreas Krallinger and Mario Reinhold demonstrate how to promote your soil microbiome in practice. In another article entitled 'How cover crop mixtures activate the microbiome', they show how the theory of promoting the microbiome can be put into practice.

Prof. Dr. Christel Baum
Faculty of Agriculture,
Civil Engineering and the
Environment, University of Rostock
E-Mail: christel.baum@
uni-rostock.de