Summer 2020

Bild: J. Garget/pixabay.com

Editorial

Microorganisms - valuable assistants for sustainable soil management

Soils are complex, dynamic ecosystems and habitats for countless organisms. Microorganisms such as bacteria and fungi decompose dead plant material into available nutrients and are, thus, of great importance for soil fertility and agriculture. However, among the good guys there are always some bad guys, who damage the plants as pathogens. There are clear indications that the composition of the biotic communities in soil is crucial for the balance between useful microorganisms an pathogens. However, we know far too little about these interrelationships to specifically profit from these interactions in agriculture. The BonaRes project DiControl has set out to increase the necessary knowledge.

DiControl aims to find out how microbial communities in the soil are composed, how they differ from plant species to plant species and in which processes in the root zone they are involved. In the future, it should be possible to steer microbial communities in agricultural soils in such a way that they improve the nutrient supply of the crops and thus reduce the need for fertilizer. On the other hand, bacteria and fungi can act as natural plant protection and help to reduce the use of pesticides. After all, pesticides also damage beneficial soil organisms and thus impair soil fertility. Sustainable agriculture depends on species-rich, functional communities of soil organisms.

In the current BonaRes newsletter we focus on the importance of microorganisms for sustainable agriculture and introduce the DiControl project in more detail.

I wish you a pleasant reading

Hans-Jörg Vogel

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Hans-Jörg Vogel coordinates the **BonaRes Centre for Soil Research**. He studied agricultural sciences at the University of Hohenheim. Since 2005 he is head of the **Departmentof Soil System Science** at the **Helmholtz Centre for Environmental Research - UFZ** in Halle-Leipzig. His work focuses on the modelling of soils as complex systems and the influence of agricultural land use on soil functions.

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Winter wheat in long-term field experiment in Bernburg-Strenzfeld of AUAS. Photo: Doreen Babin (JKI)

In focus

Microorganisms - significance for soil and plant health

Nearly 90 percent of our food and crop products are produced with the soil. Soils are therefore the foundation of our life. But soils are sensitive ecosystems and damage is difficult to reverse within short periods of time. It is therefore important to maintain soil fertility with site-specific agricultural management.

Soil is one of the most important resources on earth. As a living and dynamic ecosystem, it provides habitat for a wide variety of life forms. This includes microorganisms such as bacteria and fungi, which are involved in almost all soil processes. One gram of soil can contain billions of microorganisms. These microorganisms are an elementary component of the soil and are of enormous importance for soil fertility and health. A healthy, fertile soil is a crucial prerequisite for plant productivity. It is therefore of fundamental importance for mankind to maintain soil fertility.

Functions of microorganisms in soil

The various soil organisms fulfil important functions. Soil organisms convert dead organic matter into plant nutrients. They also ensure that poorly soluble mineral nutrients such as phosphate, zinc or manganese are released and absorbed by the plant. Without these nutrients, plant growth would not be possible. Currently, researchers are also discussing whether microorganisms can mobilise potassium. Soil organisms further help to maintain and improve soil structure by participating in the formation of humus and soil. Fungal hyphae and organic substances, released by microorganisms into the soil, bind soil particles into aggregates. Soils with a good soil structure are more fertile because they are able to better absorb and store water and nutrients.

The close relationship between plants and microorganisms

Through their roots, plants establish relationships with soil-dwelling microorganisms by releasing organic compounds such as sugar molecules, amino acids and other organic substances into the soil around the roots. This area is also called the rhizosphere. The organic substances released by the plant roots serve as nutrients for microorganisms. Plants thus attract microorganisms which multiply in the rhizosphere and, for example, improve the availability of nutrients for the plant. The rhizosphere is thus of crucial importance for a functioning soil ecosystem.

The interactions between plants and microorganisms in the soil can be mutually beneficial. A well-known example of a mutually beneficial partnership is the symbiosis with mycorrhizal fungi, which support the

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supply of water, nitrogen and minerals such as phosphate and zinc to the plant, thus improving plant growth. In exchange, the fungi receive sugar from plant photosynthesis.

Microorganisms as plant pathogens

However, soil microorganisms also include pathogens that harm plants or negatively affect their health. It is undisputed that a healthy soil not only supports the supply of nutrients to plants, but also contributes to keeping plants healthy. Whether and what relationship a plant can establish with soil microorganisms depends, among other things, on the microbial community living in the soil.

Soil microorganisms and agriculture

Although microorganisms are an integral part of the soil, we know little about how agricultural management affects the soil microbial community. What does farming mean for the relationship between plants and soil microorganisms and how do these changes affect plant growth and plant health?

To answer these questions, scientists in the BonaRes joint project DiControl are investigating on the one hand how agricultural measures affect the composition and functionality of the bacterial and fungal community in the soil in the long term. On the other hand, they are investigating how microorganisms in the immediate vicinity of roots influence plant growth and plant health. The knowledge gained will be incorporated into new cultivation strategies for sustainable soil management, in which the use of synthetic fertilizers and pesticides can be significantly reduced while maintaining or even increasing yields.

Challenge for agricultural production

The protection of the environment, including soil fertility, is one of the greatest global challenges of our time. At the same time, agriculture should secure the increasing demand for food for a steadily growing world population as well as plant raw materials for industry such as vegetable oils for the production of detergents and cosmetics and for energy production. Sustainable crop production must therefore protect natural resources and maintain or even increase soil productivity. In intensive agriculture, as it is currently predominantly practised, large quantities of synthetic fertilizers and pesticides are used to ensure high yields. However, too intensive use of organic fertilizers such as liquid manure can also cause environmental problems through undesirable nutrient losses (nitrates) or pollutant inputs (antibiotics, heavy metals).

Already in 2011, the Food and Agriculture Organisation of the United Nations (FAO) stated that global yields in intensive agriculture, for example of cereals, have not increased since the 1990s. Why is this? Plant growth and plant health depend crucially on soil quality.

Biodiversity important for soil fertility

If a species-rich microbial community is present in the soil, soils can do more for agriculture. This is shown not only by our own investigations, but also by those of the Agroscope Research Station and the University of Zurich. Plants can absorb more nutrients and grow better if a large number of fungal and bacterial species are present in the soil.

Pesticides damage communities of microorganisms

We assume that synthetic fertilizers and pesticides have a negative impact on the microbial communities in the soil and thus also have a negative effect on plant growth and health. These are then more susceptible to pathogens that are usually controlled by synthetic pesticides - a vicious circle. After repeated and increased use of the respective pesticides, pathogens develop resistances after some time, so that their effect diminishes.

A vital soil life with high microbial diversity and activity can prevent the accumulation of pathogens in the soil and thus protect the plants from diseases. Numerous studies show that certain microorganisms help plants to defend themselves against pathogens and handle stress better. Ideally composed communities of microorganisms could help to reduce or eliminate the use of synthetic pesticides. Sustainable plant production systems should therefore treat and maintain the soil as a vital living and biological system.

Soil as a complex biological system

Plant cultivation measures evidently influence microbial communities in the soil, as has been demonstrated by various studies (AGRARForschung 13, 2006; Landinfo 4, 2018; both in German). Long-term experiments show that the way in which the soil is managed, influences the physico-chemical and biological soil properties.

In organic farming, for example, preventive crop-related measures such as versatile crop rotation, optimum soil management, the use of organic fertiliser or the supply of the soil with sufficient organic matter provide for an active soil life. Versatile crop rotation is positive for soil biodiversity, as the plant roots themselves are colonised by a multitude of microorganisms and each plant species carries a specific microbial community. We assume that the cultivation of different crops promotes a species-rich microbial community both in the soil and in the rhizosphere. Each plant releases very specific organic substances and thus builds up an optimal microbial community in the rhizosphere. As already mentioned, an active and diverse soil life can counteract the occurrence of diseases and ensure that pathogens living in the soil (e.g. *Gaeumannomyces graminis*, *Pythium* spp. or *Phytophthora* spp.) reproduce less strongly.

In current agricultural practice, however, we are usually dealing with narrow crop rotations which are restricted to only a few crop species. In such crop rotations, pathogens can accumulate in the soil over time. This example shows that crop management measures become embedded in the "memory" of the soil, so to speak.

Unfortunately, at present we still know too little about how conventional crop management measures influence the "soil memory" or soil life - especially the microorganisms associated with the plant - and thus plant health. The aim of the research of scientists in DiControl is to better understand the interactions between plants and microorganisms in agroecosystems and thus to decipher the memory of the soil. The scientists are particularly interested in whether certain agronomical measures promote the accumulation of pathogens in the soil and whether the occurring microbial community can inhibit pathogens in their development. In a next step, we will then investigate whether a targeted inoculation of the plant with beneficial microorganisms supports these processes. On this basis, recommendations for sustainable plant production in conventional agriculture will be developed.

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Rita Grosch (IGZ) and Kornelia Smalla (JKI)

Rita Grosch is head of the programme area **Plant-Microbe Systems** at the **Leibniz Institute of Vegetable and Ornamental Crops (IGZ)** in Großbeeren. She studied biology with a focus on plant physiology at the Humboldt-Universität zu Berlin. Her research focuses on interactions of plants with pathogens and beneficial microorganisms. A better understanding of these interactions at the molecular level and with the environment should help to control plant diseases in an environmentally friendly way. She has been coordinating the **Bonares** joint project **DiControl** since 2015.

Kornelia Smalla is deputy head of the **Institute of Epidemiology and Pathogen Diagnostics** at the **Julius Kühn Institute (JKI)** in Braunschweig. For more than two decades, she has been using molecular methods to investigate microbial communities in the rhizosphere of cultivated plants and is interested in how various abiotic and biotic factors influence the composition and dynamics of the rhizosphere microbiome. Since 2015 Kornelia Smalla is leading the DiControl project at JKI.

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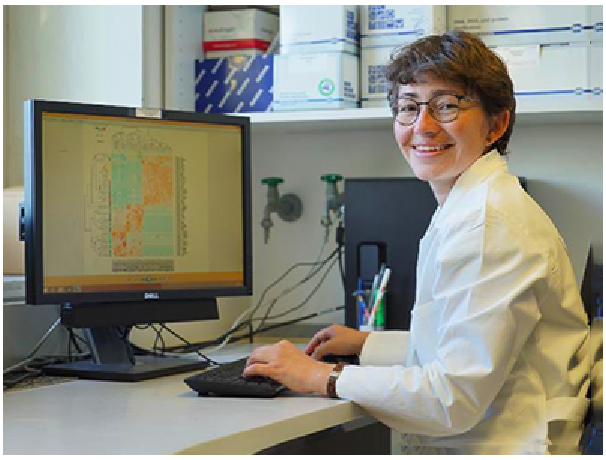

Doreen Babin at work. Photo: Xorla Kanfra (JKI)

Portrait

Doreen Babin – At work for microorganisms

Doreen Babin has been working as a research assistant in the BonaRes joint project DiControl at the Julius Kühn Institute in Braunschweig since 2015. She is investigating the influence of agricultural practice on bacterial communities in the soil and root zone. In close cooperation with her project partners, she is assessing the importance of these microorganisms for plant growth and health. In the following, Doreen Babin introduces herself and her work in more detail.

I became interested in nature, animals and plants at an early age and often roamed after school equipped with a determination book and looking for interesting new observations through my parents' garden and across the surrounding fields. At home, I then looked at what I had collected with a simple microscope. In school, however, languages and music were the focus of my interest and it was only at my A-levels that my interest in the natural sciences reappeared and influenced my decision about my professional career.

Step by step towards science

At the University of Applied Sciences Mittweida/Saxony I studied environmental technology/biotechnology. Thanks to the technical and practical orientation of the university, these studies gave me a comprehensive insight into various areas of environmental technology, from the remediation of contaminated sites to environmental hygiene and pollutant analysis. It was clear to me early on that I would like to specialise in biological topics. I wrote my diploma thesis at the Fraunhofer Institute for Cell Therapy and Immunology in Leipzig. In a mouse model I investigated how small RNA molecules influence the formation of embryonic stem cells into bone cells. This is important, for example, to gain a better understanding of the development of bone diseases. Moving from the small town in Central Saxony to Leipzig and with it from application-oriented studies with intensive all-round supervision to scientific work with a lot of self-organisation, discipline and personal responsibility was a major change at first. However, after a short period of adjustment I discovered my passion for science. In conversations with fellow students who were doing their research on plants and microorganisms, among other things, my childlike curiosity flared up again and I realized that my destiny was not in medical but in environmental research.

Some hurdles had to be overcome on my way

I was lucky and came across a job advertisement at the Julius Kühn Institute (JKI) in Braunschweig, which corresponded exactly to my interests and offered the possibility of a doctorate. Despite Professor Kornelia Smalla's immediate acceptance to supervise my doctoral thesis, however, a number of bureaucratic hurdles still had to be overcome in order to become – as a graduate of a University of Applied Sciences –

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eligible for a doctorate. In retrospect, however, this turned out to be a fortunate circumstance, because it gave me the opportunity to acquire some additional qualifications in the field of bioinformatics. The working group at the JKI consisted of colleagues of many different nationalities, who immediately welcomed me with an open heart and helpfulness, thus making it easier for me to start my career in the new city. I wrote my doctoral thesis as part of a priority project of the German Research Foundation (DFG) on "Biogeochemical Interfaces in Soils". I investigated how the formation, composition and effects of soil microbial communities depend on the soil mineral composition. I was particularly interested in the complex interactions between the various living and non-living soil components such as fungi, bacteria, humus and mineral particles. However, one important piece of the puzzle was missing in this interaction: the plant.

DiControl offered the optimal research question

Therefore, I was immediately enthusiastic when I heard about the DiControl project after finishing my PhD, a project which combines the components soil and plant and offers the possibility to transform scientific results into agricultural solutions. But it also meant that I had to familiarize myself with several new research topics and investigation methods.

New findings in microbial ecology were always linked to technological progress. Already during my doctorate it became obvious that sequencing techniques would become the major application in the future. This method generates very large amounts of data, which have to be processed by computer-aided programs. This initially presented a new challenge for me, but ultimately I benefited from my bioinformatics knowledge from my postgraduate studies. In the meantime, it is exactly this combination of laboratory work and data analysis that makes the work in the project so interesting and versatile for me.

It is particularly important to me to inspire young scientists for research and to pass on my knowledge. Therefore, I regularly supervise bachelor and master students and support doctoral students during their work.

Microorganisms as daily companions

In my spare time, I am also constantly working for microorganisms and promoting them. Despite common belief, microorganisms are not only the cause of diseases. An enormous variety of microorganisms live with us every day: on our skin, in our intestines, in our food or in the environment. Although we still know little about the tasks of individual species, it seems to be the interaction of the multitude of microorganisms that is important for our health, that of plants and the ecosystem.

Making a contribution to sustainable agriculture in the future

I hope that my research will one day help to understand the soil microorganisms that are beneficial for crops, so that we can support them in a targeted way and thus keep pathogens at bay. This would be an important element of a more sustainable agriculture, where less pesticides and fertilisers are used.

Doreen Babin (JKI)

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Doreen Babin is a senior scientist at the **Institute for Epidemiology and Pathogen Diagnostics** of the **Julius Kühn Institute** in Braunsschweig. Since 2015 she is working in the **BonaRes** joint project **DiControl**.

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Treatment of maize plants with beneficial microorganisms in field trials. Bild: Peggy Gabor (IGZ)

Insights

Plant protection with microorganisms instead of pesticides

Microorganisms live not only in the soil but also in and on plants. Among them there is a multitude of beneficial microorganisms. They can strengthen the plant's defence against pathogens and ensure that pathogens in the soil do not multiply so strongly. Beneficial microorganisms can help to reduce the use of pesticides in agriculture.

Almost all plant species are susceptible to various pathogens, which in extreme cases can destroy an entire harvest. In conventional agriculture, farmers try to reduce the economic damage caused by diseases by applying synthetic crop protection products. However, despite the use of pesticides, yield and quality losses of 20 to 30 percent per year for economically relevant crops (e.g. potato, sugar beet, wheat) are possible in Europe due to soil-borne pathogens such as *Rhizoctonia solani*, *Fusarium* spp.

Soil-borne pathogens difficult to control

As these pathogens belong to the microbial community in the soil, they are difficult to control. In the past, these pathogens were often controlled with methyl bromide. However, fumigation with methyl bromide damaged the entire soil microbial community, which is so important for soil quality. An environmentally friendly plant protection measure is the cultivation of resistant crops. But against a large number of soil-borne pathogens there are no resistant crops available. Many crops, however, show varying degrees of susceptibility to the above-mentioned soil-borne pathogens. One speaks in this case of a quantitative resistance, which is, however, determined by a multitude of genes and can therefore only be handled to a limited extent by breeding or genetic engineering.

Plant protection products are only partially effective against soil-borne pathogens and in addition harmful to the environment. The current economic conditions in conventional agriculture reward high yields in particular, which are achieved through the intensive use of agrochemicals. Furthermore, the conditions also favour the cultivation of potential host plants in short crop rotations. Soil-borne pathogens multiply through the frequent cultivation of host plants and thus accumulate in the soil. This in turn promotes the occurrence of plant diseases.

Microbial communities as natural defense system in the soil

Many soil-borne pathogens first feed on organic matter in the soil before they attack or infest a plant. How a pathogen develops in the soil is as well influenced by the composition and activity of the soil microbial community. Whether microbial communities are able to reduce the occurrence of diseases ("soil suppressiveness") is of fundamental importance for soil quality and soil health. Our suppressiveness

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studies show that the microbial community also responds to the accumulation of pathogens. A clear relationship appears to exist between the diversity of microorganisms in the soil and its ability to suppress soil-borne pathogens.

We still know too little about the underlying mechanisms of how the soil microbial community needs to be composed in order to inhibit the development of pathogens in soil and thus reduce diseases. Therefore, within the framework of DiControl, we are investigating not only the composition of the microbial community in the soil, but also the occurrence and severity of plant diseases in differently managed soils as well as in different locations with different soil properties. We are interested in whether certain microorganisms can suppress diseases. Application of microbial inoculants in a targeted manner in plant cultivation or specific promotion of native soil microbes by certain agronomical measures can contribute to securing yields and reducing the use of pesticides in sustainable agriculture.

Jan Helge Behr is a research assistant in the **programme area Plant-Microbe Systems** at the **Leibniz Institute of Vegetable and Ornamental Crops (IGZ)** in Großbeeren. He studied biology with a focus on plant physiology at the Rheinisch-Westfälische Technische Hochschule Aachen. Since 2019 he has been working in the BonaRes joint project **DiControl** with the main focus on the investigation and establishment of potentially disease-suppressing and plant growth-promoting microorganisms to improve soil health. (Photo: Peggy Gabor, IGZ)

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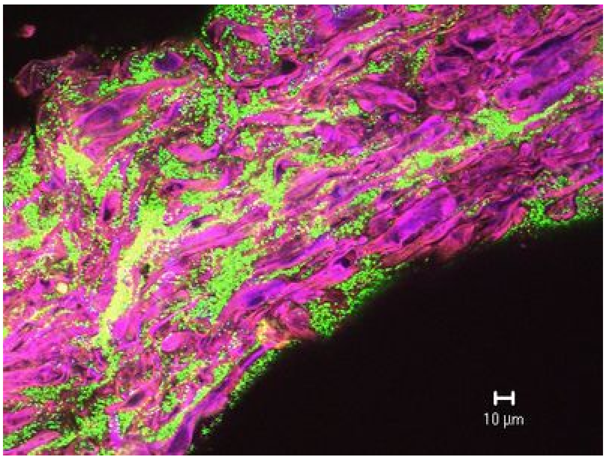

Colonization of plant roots with beneficial bacterial strain (*Bacillus amyloliquefaciens).* Photo: Soumitra Paul Chowdhury (HMGU)

Insights

Using microorganisms to promote plant health

Beneficial microorganisms can play an important role in the fight against pathogens and many other stressors to which plants are exposed. By selecting and adding the right microorganisms, we can help the plant to develop healthily even under stressful conditions.

By adding certain particularly effective bacteria or fungi to the seed before or shortly after sowing (inoculation), it is possible to provide the plant with targeted support in recruiting beneficial microorganisms. Ideally, the microorganisms (inoculants) used should be specifically selected to match the host plant, the desired effect (e.g. resistance to pathogens, drought stress, nutrient deficiency) and the soil conditions. With regard to the commercial use of inoculants, much progress has been made in recent years. Various German and international companies have discovered the development of such "microbial beneficials" as a new field of business or even specialised in this field. For example, Bacillus preparations are used to treat seeds of maize, potatoes, various vegetables and ornamental plants. The inoculation of the seeds leads to an increase in yield of five to ten percent and/or to reduced use of fertilizers and pesticides.

Inoculation: Plant protection with beneficial microorganisms

In order to be able to positively influence crops under field conditions in a targeted manner, we need to understand the wealth of interactions between plant species, soil and microorganisms even better. This is where the DiControl project makes its contribution. We not only investigate the composition of the microbial community in the soil but also whether this can be improved by beneficial microorganisms (inoculants) with which the plants are treated. In previous projects, combined inoculants of bacteria and fungi have been shown to have a disease-suppressing effect on crops such as corn, potatoes or lettuce. Our aim is to reduce the accumulation of pathogens in the soil and to promote plant health by treating corn and wheat in the field with these inoculants.

Interactions between plant, soil and microorganisms

By releasing organic compounds into the soil via their root system (exudation), plants are able to influence the microbial community in the root zone. Root exudates contain nutrients and act like small oases for microorganisms compared to the surrounding soil, which is poorer in nutrients. Plants thus attract beneficial microorganisms from the surrounding soil, which then compete with pathogens for the habitat at the root. This alone considerably reduces the number of possible pathogens. In addition, these beneficial microorganisms also have direct and indirect mechanisms, for example the production of

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antibiotics or the stimulation of plant defence to keep pathogens at bay. Which and how many beneficial microorganisms are present is presumably strongly influenced by soil properties. Field studies also show how the plant itself influences the microorganisms living in the soil and that the microbial community reacts to properties of the root (growth, length, formation of fine roots) including root exudation.

Improving the understanding of the influence of soil properties and agricultural measures on microorganisms

We also observe that the disease-suppressing effect of soil microorganisms also depends on soil properties. Furthermore, it is clear that agricultural measures influence the microbial community in the soil. In order to ensure soil health and plant productivity in the long term we must, however, gain a better understanding of the influence of different farming practices on the composition and function of soil microbial communities.

Soumitra Paul Chowdhury (Helmholtz Zentrum München)

Soumitra Paul Chowdhury is a researcher at the **Institute for Network Biology** at **Helmholtz Zentrum München**. His research area is the investigation of interactions between microbes and plants with a focus on plant growth promoting bacteria. Since 2015 the PhD biotechnologist has been working in the **BonaRes** joint project **DiControl**. His central tasks include the molecular analysis of plant health as a reaction of the plant to long-term agricultural management measures and the investigation of microorganisms in the root zone. The close cooperation and scientific communication with the project partners is particularly important to him.

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Long-term field experiment of the Anhalt University of Applied Sciences (AUAS) in Bernburg-Strenzfeld. Photo: Annette Deubel (AUAS)

Insights

Long-term experiments - central component of field research

Modern agriculture is facing enormous challenges. These include securing the growing demand for plant products while maintaining soil fertility. Long-term field experiments are therefore of great importance for modern agricultural research, as they allow the comparison of different agricultural systems.

In our project we are interested in whether and how long-term agricultural measures influence the microbial community in the soil - we also speak of the "memory of the soil" - and the occurrence of diseases or plant health. In agricultural practice, cultivation methods vary because farmers have different specializations and, for instance, only grow certain crops. Arable soils and crop production systems are to be regarded as complex ecosystems influenced by site conditions such as soil properties and climate. In order to be able to make a scientific statement on how agricultural measures affect the memory of the soil, a large number of studies, for example on the influence of ploughing or no-tillage, including the type of fertilisation (mineral versus organic fertilisation), would be necessary at a large variety of locations.

Investigation of agricultural management under field conditions

Long-term experiments are used to investigate the effects of various agricultural measures (such as tillage, type of fertilisation or crop rotation) under field conditions on one site over a long period of time. In Rothamsted (England), the oldest long-term agricultural experiments (established between 1843 and 1856) contribute to a better understanding of today's agriculture. There, for example, scientists are studying the effects of farming practices on biodiversity and soil functions in a grassland experiment. In Therwil, Switzerland, the DOK experiment (D=biological-dynamic; O=biological-organic; K=conventional) has been comparing organic and conventionally farmed arable plots since 1978. In order to achieve comparable results, the agricultural methods used in long-term experiments are kept constant over long periods of time. Therefore, the effect of different farming methods can be investigated in a system comparison, so to speak. Initially, system comparisons focused primarily on crop yields, but interest has now shifted to central ecological issues. For example, the effects of conventional and organic farming can be compared at different levels (e.g. yield, soil properties, microbial communities, biodiversity). Scientists from different disciplines work together in an interdisciplinary way to better understand plant production systems. Long-term experiments are therefore of great importance in agricultural research.

Comparison of different agricultural practices

In DiControl we also use long-term trials to investigate the effects of different agricultural practices. For example, the long-term experiment "Westerfeld" of the Anhalt University of Applied Sciences (AUAS) in

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Bernburg-Strenzfeld (supervised by Prof. Annette Deubel) enables us to investigate the influence of tillage, fertilisation and crop rotation on microorganisms in the soil. Here we compare plough and cultivator tillage areas, standard nitrogen fertilization and reduced nitrogen fertilization as well as different crop rotations. Our results clearly show that the type of tillage and crop rotation influences the microbial community in the soil but also in the rhizosphere. For example, the microbial biomass in the soil is significantly higher under reduced tillage and nitrogen fertiliser application than under ploughing. In the case of our model plant lettuce, we were able to demonstrate improved plant health. The lettuce plants were less affected by a soil-borne pathogen. We were also able to show that *Fusarium* enriched in the soil after cultivation of wheat. The community of mycorrhizal fungi also responded to the cultivation method.

Conventional agriculture versus organic farming

The demonstration facility "Ackerbausysteme" of the "Humboldt Universität zu Berlin" in Thyrow (supervised by Dr. Kathlin Schweitzer and Dipl.-Ing. agr. Michael Baumecker) enables us to compare conventional and organic cultivation. The results of these investigations underline the influence of the type of fertilization on the microbial community in the soil and rhizosphere. Our model plant lettuce proved to be healthier if it was cultivated in soil that was always organically fertilized in long-term experiments.

Interdisciplinary cooperation for a better system understanding

Of course, it is important to keep in mind that differences cannot be easily attributed to individual measures. A plant production system is very complex because, as mentioned earlier, plant and soil interact with each other. These interactions are, in turn, influenced by agronomic measures and plant protection. Nevertheless, it can be assumed that, due to the interdisciplinary cooperation of plant production, plant nutrition, plant protection, plant physiology and microbiology, we will learn from the system comparisons and will find indications which of the agricultural measures under consideration are positive for soil quality and plant health.

Loreen Sommermann (AUAS)

Loreen Sommermann has been a research associate at the **Anhalt University of Applied Sciences (AUAS)** in Bernburg since 2015 and is active in the **BonaRes** joint project **DiControl**. In her doctoral thesis she is investigating the influence of long-term agricultural measures on fungal communities in the soil and root zone. The studied ecotrophologist is not only interested in the interaction between soil, plants and the microbiome itself. It is also important to her that sustainable agricultural measures maintain soil health in order to provide high-quality food.

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Root window and root development in the field of corn (left) and wheat (right). Figure: Narges Moradtalab (University of Hohenheim)

News from the field

Root exudation - microbial community in the root area

Microbial communities in the root zone play a central role for mineral supply and plant health. Their composition is significantly influenced by root secretions (exudates), which function as nutrients, signal substances and defensive agents. However, the effects of different management measures in this context are still largely unexplained.

We are currently working directly in the field to investigate the root exudates of the cultivated crops, such as maize, wheat and rape. Compared to earlier model trials with lettuce, this poses a whole new set of challenges. Compared to pot experiments, which are carried out under very controlled conditions, root investigations in the field are much more difficult. For example, how can the root growth of crops be determined in the field without damaging the roots during excavation? And how is it possible to make statements about the composition of root secretions and soil solution in the root zone and to evaluate possible interactions with the microbial communities? These are questions that are not easy to answer even under controlled laboratory conditions.

Root windows: old method in new splendor

In the DiControl project we are now applying the well-known technique of root observation windows on a larger scale for the first time. For this purpose, steel plates are driven up to 50 centimetres deep into the soil next to the targeted plants in the early stages of plant development (from about four to six weeks after sowing or after re-sprouting in spring). The steel plates are then exposed and replaced by plexiglass plates. The pits are then loosely filled again so that the temperature and light conditions at the root observation window again correspond to those of undisturbed soil. The plants recover quite quickly when compared with plants without a root window, and in a few weeks new roots will form along the plexiglass window. We were able to show that the root growth of these experimental plants and the microbial communities in the root space do not differ significantly from undisturbed plants. This is very important for the interpretation of the test results.

The scientists now open the root windows and investigate and document the root growth along the observation plane. The photographs are later digitally evaluated.

Sampling and laboratory analysis

Subsequently, root exudates and samples of the soil solution are collected at the opened root windows. Samples are sucked out of the soil with moist filter paper that is placed on root surfaces or moistened soil

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surfaces for two to four hours. In the process, we examine root areas of different ages. Young, growing root tips are taken into account as well as older root zones behind them, because depending on the age of the root, the amount and composition of root exudates can vary greatly. The composition of the samples can be detected in the laboratory using chromatographic analysis methods.

In addition, soil samples are taken to determine microbial communities in the root area and plant tissue samples are taken for biochemical analysis and determination of the mineral composition. In this way we obtain information about the health and nutritional status of the plants. The tests are carried out prior to flowering and seed development in the so-called vegetative growth. During this period, a particularly large amount of photosynthetic products are transported into the root and root zone.

How does cultivation influence soil and plant health?

From the results we expect conclusions on how different management measures (e.g. type and amount of fertiliser and pesticide application, intensity of tillage) influence the composition of root secretions and soil solutions in the root space and how this in turn affects microbial communities at the root. The composition of microbial communities in turn influences the nutrition and health status of the plant. We therefore look at pathogens such as soil-borne harmful fungi as well as beneficial microorganisms such as mycorrhizal fungi or bacteria with growth-promoting and disease-suppressing properties. This year we are also investigating the impact of selective treatment of plants with potentially disease-suppressing and plant growth-promoting microorganisms that have previously been isolated from the root zone and propagated on suitable cultivation substrates.

Saskia Windisch and Narges Moradtalab (University of Hohenheim)

Saskia Windisch (left) started her doctoral in the **DiControl** project and helped to develop and adapt many of the techniques that are now being used in the field. She was responsible for the characterisation of root exudates in model experiments with lettuce.

Narges Moradtalab (right), who has a PhD in stress physiology, joined the project at the beginning of the second project phase. The two young scientists form a well-functioning team with great interest in the investigation of rhizosphere processes and their importance for plant development. In the first year, they have already optimised the root window technique to such an extent that it is now being used routinely. Both work at **University of Hohenheim.**

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