MiCROPe International Symposium

Microbe-assisted crop production – opportunities, challenges and needs

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A report produced by Matevz Papp-Rupar (NIAB) for the GCRI Trust

Key messages from the meeting

- The best demonstration of deploying microbial applications in commercial practice was in Brazil where biofertilisers (nitrogen fixing and plant growth promoting bacteria) were used in maize and soybean production. A combination of research funding, favourable legislation, and industry product development coupled with farm demonstrations have led to high uptake of biofertilisers, significantly reducing reliance on chemical fertiliser and water inputs, reducing carbon emissions, while producing higher yields of crops more cheaply.

- The search for plant growth promoting bacteria in Europe has been slower but has recently begun to accelerate.

- Mitigation of impending stress due to climate change is becoming one of the focal points of applied microbiome research.

- To transition from high fertiliser and pesticide food production systems towards microbiome-based food production, we need to develop context specific microbial amendments and breed new crop cultivars able to fully utilise all microbial functions for more sustainable and resilient future food production.

- Improving the current low biocontrol efficacy will require in depth understanding of how plants assemble their microbiomes, which microbes are ‘allowed’ to permanently colonise our crops and why. The first concepts of the above have emerged in recent years.

- The application of artificial intelligence (AI) to large volumes of microbiome data has enabled better understanding of plant microbiomes and improved prediction of which microbes are required/suitable in specific contexts. The AI driven precision microbiome amendments are now becoming a commercial reality offered by several companies to researchers and food producers alike. The context specific advice on microbiome amendments could result in a step change increase in the effective use of microbial solutions.

Purpose of the symposium

The miCROPe conference is a unique event focused on soil and plant microbiomes and their contributions to food production systems. Plant associated microbes provide vital functions such as nutrient delivery, stress tolerance, and pathogen or pest control. The aim of this event was to showcase the current understanding of plant-microbe interactions which are required to develop microbial products, new applications to improve crop production, and create alternatives to chemical control options for pests and diseases. The meeting focused on questions of microbial ecology. It asked which microbes are found where and why, how microbes interact with plants and other microbes, and how microbiome assemblies and their function changes due to climate change.

The hope is that greater understanding of microbiome functioning will also lead to new routes of exploration and exploitation. In line with the previous miCROPe conferences, miCROPe 2024 aimed to provide content to scientists in academia as well as in industry and to facilitate joint discussions. The sessions addressed:

1. different functions of microorganisms in crop production, ranging from biocontrol to nutrition and stress resilience,
2. the mechanism of plant microbe interactions,
3. how microbiome research can be translated to field applications.

Star presentation

The star presentation which received a standing ovation in the session on microbial application into practice, was given by Mariangela Hungria from Embrapa, Brazil. Brazil has a long tradition of research and utilisation of microbial biofertilisers going back to the 1950s. They first focused on microbes for biological nitrogen fixation and more recently on microbes for root growth. The collaborative efforts of research, industry, policymakers and extension agronomists have achieved an 85% annual adoption rate of nitrogen fixing bacteria (*Bradyrhizobium* strains) in Brazilian soybean production. Replacement of N-fertiliser with biological nitrogen fixers resulted in annual savings of over 25 billion USD, mitigated the emissions of about 240 million tonnes of CO_2 (equivalent annually) and reduced Brazil's dependency on fertiliser imports and related price spikes.

In the last ten years, microbes with phytohormone synthesis capabilities, enhancing root growth and, consequently, fertiliser use efficiency and water uptake (e.g. *Azospirillum brasilense*) have been adopted by the Brazilian market. It is estimated that 22% of summer maize, 44% of winter maize and 38% of soybean in Brazil is now produced using a new approach combining nitrogen fixing and plant growth promoting bacteria. In soybean co-inoculation with *Bradyrhizobium* spp. and *A. brasilense* has doubled the increase in grain yield in comparison to the single inoculation. The next targets in the Brazilian bioinoculant pipeline are inoculants for improved phosphorus and potassium nutrition.

The remarkable rate of adoption of this new technology in Brazil has been made possible by continuous funding of research. The focus on microbial strain discovery, mechanisms of action and their practical use, government funded translation strategy, coupled with legislation that promotes the use of local nature-based solutions, has helped to foster entrepreneurship and private investment. Europe and the rest of the world are clearly behind Brazil when it comes to biofertilisers, but the profile of R&D developments in the field of biofertilisers has been raised by Sofie Goormachtig (University of Ghent, Belgium) who led the hunt for better strains of nitrogen fixers for European legume production. Charlotte Klank (Alphea Bio, Bel) has also alerted us to the new product development pipelines adopted by the industry to accelerate the replacement of chemical fertiliser and pesticides in Europe.

Climate change

There were many talks and discussions on climate change mitigation using beneficial microbes. The focus was on the effect of drought, heat, salinity, cold and nutrient depletion stress on the microbiome assembly, function and plant productivity.

Salinity stress in soil grown tomato has been investigated by several researchers. They applied, gradual microbiome evolution with higher salt levels (Salila Pradahan, India), or transplanted microbes from natural high salinity ecosystems (Beatriz Ramos-Solano, Spain) to increase plant growth in saline conditions.

One of the most interesting examples of microbial use for climate change mitigation came from Prof. Magen Saad from Saudi Arabia. Prof Saad presented the holistic approach they used to harness the potential of beneficial root associated microbes of desert and mangrove plants. They employed microbiome, transcriptome, and metabolome analyses to identify key microbes responsible for salt and drought tolerance in extreme ecosystems, described plant responses to those key microbes that resulted in increased stress tolerance, and demonstrated enhanced resilience and productivity of rice in arid regions utilising new microbial amendments. Such microbial products could unlock land that is currently unsuitable for crop production whilst safeguarding production of current land that is being threatened by climate change.

Knowledge gaps

A large part of the conference was dedicated to talks and discussions on knowledge gaps in our fundamental understanding of plant microbiome interactions required for widespread adaption of nature-based solutions. In this session the outstanding talk was given by Prof Phillippe Vandenkoornhuyse (Rennes, France) who discussed two challenges or fundamental shifts in the way we think about food production that will need addressing if microbial based solutions are to replace chemical inputs.

The first challenge has been known for some time and has now been named the ‘Anna Karenina’ principle. The name is based on the opening lines to the novel by Leo Tolstoy: “All happy families are alike; each unhappy family is unhappy in its own way”. It means that each of our food production challenges have specific problems and will thus require regional (climate, soil type), crop type and stress dependent sets of solutions. The key is not to try to find one microbe that will work in all contexts but to understand which microbe to apply where, when and how. To do this the world’s governments will need to legislate to allow more flexible policies to enable multitude of products to reach the end users. The glasshouse production sector with a more consistent and reproducible environment may be the first sector to adopt such a targeted strategy.

The second challenge is to transform breeding programmes to select for high yield, quality and resilience with beneficial microbe associations in mind. Currently, we breed our crops in high fertiliser and high pesticide inputs conditions. The new varieties selected that way are the ones that perform best in high nutrient and high plant protection environments and are not necessarily suited for using microbes as an alternative. Furthermore, plant association with microbes in such conditions may result in a yield penalty compared to plants that do not associate with microbes. As a result, we might be slowly losing or removing the capacity of our crop varieties to 'talk' and 'use' microbes for their growth and protection. The result may be that no microbe amendment we develop is ever going to improve the growth of such microbiome incompatible varieties. If we are to replace chemical inputs in food production and safeguard crops against climate change with microbial solutions, then breeders need to start breeding now for the future crops with better microbiome compatibility.

To improve plant-microbe interactions we also need to understand which microbial properties are required in particular crop-environment-stress scenarios. Prof Simona Radutoiu (Aarhus, Denmark) presented seminal work on microbiome assembly in model and crop plants. Her group discovered that Arabidopsis, Barley, and Lotus plants recruit bacteria from highly complex synthetic communities (SynComs) and despite their taxonomic diversity, bacteria enriched by the three plant species harbour set of 266 functions common among all hosts. This work sheds light on key functions and principles guiding the recruitment of bacterial isolates into plant roots that will be required for microbiome engineering and inoculant discovery in the future.

Another relatively new approach to microbial solutions in agriculture is the so called 'One Health' approach. Prof Gabrielle Berg (Graz, Austria) has presented recent research on the topic and had argued that the health of humans and crops are interlinked and should be therefore managed together. Her studies indicated that plant microbiomes have changed due to anthropogenic factors such as biodiversity loss, pollution, ozone depletion and climate change. Plant microbiomes nowadays are often dominated by a few species with capacity to hypermutate, resist antibiotics and other stresses. This can lead to missing symbionts on one hand and outbreaks of pathogens in the other. The microbiome of our food is connected across systems and is crucial for planetary health issues.

Data science

The last session focused on data science and the utilisation of artificial intelligence in microbiome research and application. This cutting edge field is still dominated by academic research such as that presented by Martin Hartman (Switzerland) and Livio Antonelli (Austria) that grapples with how best to use AI to analyse microbiomes, find patterns in vast amounts of microbiome sequencing data, find out which microbes are missing or present in too high abundance and thus causing problems for our crops. The main aim is to use AI models to develop and prescribe precision microbial products required for specific challenges.

It is very exciting that AI approaches for microbiome discovery and application are now breaking into commercial reality. We heard from Alex Jousset (Cybiome Gmbh, Switzerland), Michael Ionescu (Lavie-Bio Ltd, Israel) and Sascha Patz (Computomics GmbH, Germany) on their latest solutions. For example, Cybiome Gmbh is offering AI driven precision microbiome predictions that can identify the most effective microbial amendments for enhancing microbiome-informed plant breeding, soil restoration, and agrochemical-free food production. Lavie-Bio Ltd have taken a different approach and are using AI to predict which of the thousands of microbes in research biobanks have the potential to, first be developed into products (scale up, shelf life, formulation) and second, to colonise the plants. Their approach already yielded a new commercial biostimulants and bio-fungicide.

Networking

On top of the great talks and presentations, MiCROPe 2024 also offered ample opportunity for networking, discussions and developing new research links with some of the best emerging and established researchers from industry and academia. I had constructive discussions during the breaks, poster sessions and other social events such as the visit to the ZOO and the conference dinner. With Kristin Hauschild (Julius Kuehn Institute, DE) and Anja Logo (Agroscope, CH) we discussed the pitfalls of current approaches to assessment of microbial functions in soils. With Ahmed Abdelfattah (Leibniz Institute of Agricultural Engineering and Bio-economy, DE) we delved into apple microbiome assembly, the role of cultivars in the process and the role of apple microbiome in the resistance to diseases and abiotic stress. Beyond my personal subject of biocontrol, I also had some fruitful discussions on methodology and new developments in the field of beneficial arbuscular mycorrhizae in agriculture with Cem Turanoglu (Université de Rennes, FR) and Natalie Ferro Lozano (Wageningen University, Netherlands).

Overall, miCROPe 2024 was a wonderful event to attend. I have learned many new concepts and met many new people, which will be crucial for the future direction of my research at NIAB’s East Malling site.

Contact details:

Matevz Papp-Rupar, NIAB, East Malling, ME19 6BJ matevz.papp-rupar@niab.com

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