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Editorial

Editorial: Special thematic issue on microbe-assisted crop production

Crop production is globally impacted by climate change and demographic development. The increasing world's population, diminishing land resources, extreme weather events, highly variable weather conditions and emerging pathogens require new solutions. Furthermore, many pesticides and inorganic fertilizers are harmful for human/animal safety and our environment; therefore, in several countries legislation has demanded lower inputs and sound agricultural management. Considering the fact that food production has to be substantially increased in the coming decades to feed the world's growing population, there is an urgent need to develop novel approaches to combat biotic and abiotic plant stress enabling a sustainable agricultural development.

Similar to the human gut, plants are associated with complex microbiota, which are important for the physiology and functioning of their host. Microbiota associated with guts or plants confer important functions such as nutrient uptake, antagonism of invading pathogens, protection against stress and providing metabolic capacities (Berendsen, Pieterse and Bakker 2012; Ramírez-Puebla *et al.* 2013; Hardoim *et al.* 2015). Aleklett and Hart (2013) suggested the plant microbiome as an extension of the host genotype. Well known are interactions between plants and mycorrhizal fungi or between legumes and nitrogen-fixing bacteria, all which are very important for nutrient cycling and uptake and which are a very important contribution to sustainable crop production. However, many more beneficial interactions are known, and a high number of different microbial taxa comprise strains with plant beneficial functions. Due to these mutualistic interactions various developments are on-going to develop microbial solutions in crop production. The application of microbial inoculants as biofertilizers or biocontrol agents/biopesticides in crop protection holds great potential. Such inoculants may comprise single strains or designed microbial consortia with synergistic effects. Current efforts aim not only at the selection of suitable strains, but also at the development of appropriate application technologies. Alternatively, approaches may be developed to modulate plant microbiota leading to more efficient and beneficial interaction with their host or the selection and development of plant genotypes being able to efficiently interact with their microbial partners.

For understanding the dynamics and functioning of plant microbiomes it is crucial to address the ecology of plant–microbe interactions. We have to obtain more knowledge on the drivers of plant-associated microorganisms and how they affect diversity and functioning. A better understanding has to be elaborated on the functional capacities of the plant hologenome comprising plant and associated biota (Jefferson 1994; Mitter, Pfaffenbichler and Sessitsch 2016) and how diverse functions are regulated. Currently, only some mechanisms are known as to how microorganisms are able to support plant growth and health, and it can be expected that more mechanistic understanding will be obtained on plant beneficial microbial activities. Furthermore, we are just at the beginning of understanding multitrophic interactions, which might even revolutionize our perception of plant microbiomes.

In November 2015, the symposium 'Microbe-assisted crop production—opportunities, challenges and needs' (miCROPe 2015—www.micrope.org) was held in Vienna, Austria, and addressed basic and applied aspects of applying beneficial microorganisms in crop production. The symposium also represented the final conference of the COST Action FA1103 (Endophytes for Biotechnology and Agriculture—www.endophytes.eu). After an opening statement and an opening lecture on ways how to integrate microbial solutions in a sustainable agriculture and current microbial applications, the miCROPe 2015 symposium had seven scientific sessions covering mechanistic understanding of beneficial plant–microbe interactions, colonization aspects, microbiome research, transfer of microbial applications from lab to field, formulations and registration issues. In addition, a roundtable discussion, with stakeholders from different sectors, was held to discuss registration and farmer-relevant issues. The miCROPe 2015 symposium closed with a talk on the potential of fungal endophytes. More than 250 delegates from 48 countries participated in this symposium. The symposium was accompanied by two satellite workshops on 'Applications of endophytes and their secondary metabolites to combat phytopathogens' and on 'Emergence of human pathogens from natural and agricultural environments'.

The current thematic issue on Microbe-Assisted Crop Production of *FEMS Microbiology Ecology* contains peer-reviewed papers based on presentations given at the miCROPe 2015 symposium as well as other submissions received on microbiology ecology related aspects of plant–microbe interactions. Contributions address novel aspects of nodulating bacteria, endophytic colonization and performance, seed priming by microorganisms, weed-associated microbiota and microbiome analysis of yet unexplored plant environments. Several contributions deal with novel aspects of plant beneficial bacteria such as functional aspects of endophytes of the non-nodulating legume Marama bean (Chimwamurombe, Grönemeyer and Reinhold-Hurek 2016) or the association of common bean with betaproteobacterial rhi-

zobia (Dall'Agnol *et al.* 2016). The role of volatiles produced by *Bacillus amyloliquefaciens* for biocontrol and plant growth promotion was investigated (Asari *et al.* 2016) as well as the exchange of metabolites such as tryptophan, thiamine or auxine between *Chlorella* and *Azospirillum* (Palacios *et al.* 2016). Furthermore, the ecology of fungal endophytes, e.g. in modern and ancient wheat ancestors, was explored showing that modern lines lack several endophytes with potentially important traits (Ofek-Lalzar *et al.* 2016). Zhou *et al.* (2016) demonstrated the effects of the fungal endophyte *Chaetomium globosum* against various cotton herbivores, while Schlegel *et al.* (2016) investigated the interaction between different *Fraxus* species, the ash dieback-causing fungus *Hymenoscyphus fraxineus* and fungal endophytes. Several contributions studied microbiome interactions with plants such as the diversity of diazotrophic bacterial communities associated with plants grown in native and agricultural desert ecosystems (Köberl *et al.* 2016). Another study revealed that naturally growing and cultivated *Cyclopia* species (used as herbal tea) showed highly similar microbiomes, which were affected by environmental conditions (Postma *et al.* 2016). Liebe *et al.* (2016) studied the effect of various storage conditions on sugar beet-associated fungal and oomycete communities showing the rot development is associated with causal agents of post-harvest diseases. Another study revealed different core rhizosphere microbiome components of potato cultivated at different sites in the Andean altiplano in Peru (Pfeiffer *et al.* 2016). Furthermore, the investigation of Mercado-Blanco *et al.* (2016) on the olive endophyte *Pseudomonas fluorescens* PICF7 revealed that this strain is also able to colonize cereals, but promotes growth of only barley. Two publications deal with phytoremediation-related aspects. Berthelot *et al.* (2016) analyzed dark septate endophytes of poplar trees growing in metal-polluted sites and identified strains with the potential to improve production of bioenergy crops such as poplar in polluted soils.

This issue also contains some relevant review and perspective papers. Card *et al.* (2016) reviewed the accumulating knowledge on endophyte biology and discussed its importance to develop successful biocontrol products. The functional capacities of *Streptomyces*, which is an important member of plant microbiota, were reported by Viaene *et al.* (2016). Mahmood *et al.* (2016) presented the potential of seed priming with plant growth-promoting bacteria, whereas the role of weed-associated microbiomes and their role in weed control were reviewed by Trognitz *et al.* (2016). This thematic issue will stimulate further research on plant microbiota providing the basis for a better understanding of the multiple interactions taking place in the plant environment.

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