EDITORIAL

# *The importance of the plants, fungi and bacteria network in maintaining sustainable plant production*

The global demographic explosion triggers an alarming situation of food demand. This implies sustainable plant production through the rational and healthy use of long-term soils. This can only happen by reducing the use of chemical fertilizers and pesticides since they have toxic effects on the health of the soil and the ecosystem in general. However, to maintain plant production, it is essential to seek other more effective and sustainable alternatives. Soil harbors a panoply of interactions between the major players in the rhizosphere, mycorrhizal fungi and plant growth-promoting bacteria, which improve plant growth, health and development. These beneficial interactions lead to additive and/or synergistic effects which translate positively into the sustainable production of agrosystems and stop the use of products with toxic effects on the ecosystem.

In return to nature, for better resistance to biotic and abiotic stress, and efficient absorption of water and nutrients; the majority of terrestrial plants are forced to associate with mycorrhizal fungi. As a result, mycorrhizae have attracted more attention, but unfortunately, apart from bacteria which represent the third component of mycorrhizal associations. The rare studies on this subject show the close association between mycorrhizal fungi and the associated bacterial flora. These latest advances should change our way of seeing mycorrhizal symbioses and redefine mycorrhizae as tripartite associations. Therefore, it is necessary to expand research on the understanding of plant-fungus-bacteria interactions and the use of this tripartite association as bioinoculants to improve plant production; in order to meet the increasing demand for nutrients.

The importance of the third bacterial partner comes from the fact that these prokaryotic microorganisms are associated with symbiotic fungi during the different stages of their life cycle. They colonize mycorrhizal roots, extraradical hyphae, sporocarps and also live in the fungal cytoplasm as endobacteria. However, those identified as endobacteria should be given more importance, despite the difficulty that they are not culturable outside of their hosts. Because these endobacteria are widespread in mycorrhizal fungi, 10 out of 11 Gigasporaceae isolates contain endobacteria. Also, are themselves obligatory symbionts of plants, thus proving the direct link between the fungus and the plant. In general, the rhizospheric bacterial flora are responsible for multiple auxiliary effects on the development of mycorrhizal symbiosis. These beneficial effects can take place on the host plant or the associated mycorrhizal fungus. These effects can be summarized in the following points:

- Facilitating the acquisition of nutrient resources through the solubilization and mineralization of different nutritional resources and the fixation of atmospheric $N_2$.
- Improving the resistance of plants to pathogens by competition for space at the root level, the triggering of systemic resistance induced in plants, or also by a direct effect on the pathogen; through the production of antimicrobial compounds that restrict the functioning of pathogens and the production of enzymes that lyse the cell walls of oomycetes and pathogenic fungi.
- The production of phytohormones, including indoleacetic acid, cytokinins, gibberellin, aseismic acid, salicylic acid, brassinosteroids and jasmonate, which regulate the development of the root system to become more receptive to mycorrhiza.

- Stimulation of fungal spore germination and enhancement of presymbiotic growth of the mycorrhizal fungus; through increased elongation and branching of hyphae and maintenance of the saprophytic life of fungi until the development of plant roots to form mycorrhiza.

On the other hand, several bacterial strains with different beneficial mechanisms can act in synergy and complement each other to improve the growth and production of host plants as well as create a sustainable balance in the entire ecosystem. Therefore, there is considerable interest in deciphering the mechanisms of tripartite interactions between mycorrhizae, bacteria and plants in order to build an excellent strategy for sustainable agricultural production. In summary, rhizospheric interactions between mycorrhizae and bacteria are vital to improve plant production and fight against various biotic and abiotic stresses. Therefore, the final objectives will be to understand the complex interactions established by the trinomial mycorrhizal fungi - plant cells - bacteria, in order to be able to develop highly productive models in sustainable agriculture. To achieve these objectives, it is essential to rely on new high-throughput sequencing methods and invites the scientific committee to develop the following aspects:

- Develop metagenomic, ecological and functional analyzes in the mycorrhizosphere.
- Decipher the complete scenario of the development of tripartite mycorrhiza.
- Identify bacterial strains associated with fungi and mycorrhizal roots and their functional relationships.
- Identify the effects of specific bacterial species on fungi, plants or both at the same time.
- Identify the effects and mechanisms of influence on the presymbiotic development of symbiotic fungi.
- Identify the effects of fungal species and plants on the activity of the bacterial microflora of the mycorrhizosphere.
- Decipher nutritional strategies in the mycorrhizal fungus-plant-bacteria network.

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