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Editorial: Microbiome-based technologies: use of inoculants for improving agricultural productivity and sustainability

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Editorial on the Research Topic
Microbiome-based technologies: use of inoculants for improving agricultural productivity and sustainability

Since Hiltner's description of the rhizosphere in 1904, soil microbiology has undergone significant advancements, giving rise to a new era with exciting possibilities and perspectives (1). It stands at the forefront of technological development, marking a promising frontier for scientific exploration. The closer association between plants and microbes is well described in the literature. They are coevolving for several millennia, developing beneficial associations to cope with abiotic and biotic stresses and nutrient deficiency across various environmental conditions (2). This knowledge prompts us to start a new era in agriculture, where the positive interaction between plants and microorganisms could be used as an essential tool to improve productivity sustainably. Agriculture is at the core of a new paradox; it is responsible for promoting impressive environmental changes that directly impact the climate, but at the same time, this is the anthropogenic activity that is most affected by them (3). The concern about sustainability has increased in recent decades, stimulating the search for new technologies to improve production practices (4). Nowadays microbiome-based technology as microbial inoculants are a potential source for plant nutrients which has multiple direct and indirect mechanisms which modulate plant growth and development. Directly by promoting nutrient availability, such as biological nitrogen fixation from the atmosphere, solubilization and mineralization of different phosphorus sources, plant hormones productions (e.g., indole-3-acetic acid), and indirectly by eliminating plant pathogens and stimulating the induced systemic resistance (ISR) (5–7). Both direct and indirect microbial activity is valuable for agriculture.

In this Research Topic, we promoted an inventory of agricultural practices involving microorganisms and their potentiality. It is worth revisiting the past and exploring ideas and technologies to understand better and apply this knowledge about soil microbiology in productive agricultural systems. Silva et al. brought up historical aspects of crop development, such as the beginning of non-tillage management practices in Brazilian agriculture and more recent elements, such as soil microbiome providing essential ecosystem services correlated with sustainability. The authors provided a framework for soil health, an essential premise of sustainable agriculture. As living organisms, such as bacteria, fungi, soil invertebrates, insects, and many others, provide ecosystem services, it is reasonable to consider that some of the selected indicators for soil health assessment are related to soil biodiversity. Among the traits selected to compound the soil health index, the authors highlighted the incorporation of microbial biomass, respirometry, enzymatic activity and other microbiological parameters to determine the soil quality to develop highly productive agriculture. Ultimately, this article highlights harnessing beneficial plant-microorganisms interactions as an ecologically sustainable strategy for enhancing soil health.

As aforementioned, microorganisms help plant development directly or indirectly. Some microbial groups were already described as showing a narrow connection with plants, such as mycorrhizal fungi, Actinomycetota and Proteobacteria, belonging to the *Burkholderia* genus. In this Research Topic, all these groups were approached. Nasslahsen et al. described in their mini-review several mechanisms by which mycorrhizal fungi help plants to develop, especially the role of bacterial communities that grow in close association with the hyphae of mycorrhizal fungi, the hyphosphere (8). This associated bacterial community modulates the level of infectivity of these fungi, indirectly impacting plant growth.

Silva et al. approached Actinomycetota phyla, previously recognized as Actinomycetes or Actinobacteria. This bacterial group is responsible for helping plants with multiple functions, such as nitrogen fixation and increasing phosphorus availability, but especially for producing antimicrobial substances able to suppress pathogens. Silva et al. describe their metabolic versatility and the incredible capability of this group to contribute to sustainable agriculture.

Burkholderia also helps plant development. Santos et al. described the positive activities of bacteria from this genus that helped maize seed germination, followed by their improved growth. Their results may be significant to extreme soil environments like arid and semiarid regions of the globe.

As this Research Topic highlights, microorganisms have a high potential to help plant development and improve agricultural practices. Here, we opened a dialogue between the past and the future, retaking consolidated concepts and elaborating new applicability to evolve a more secure and productive agriculture. This new look at old concepts combined with current knowledge will help us to deal with the challenges of productive ways of production in a scenario of climate change. Beyond the exposed points in this letter, microbiological application in agriculture has other possibilities, such as constructing synthetic microbial communities and genetically modifying microorganisms by CRISPR-Cas system to improve a specific capability, among others (9). It begins a new agricultural era, recognized as the new green revolution and Agriculture 4.0 (10).

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