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Editorial: Plant Growth-Promoting Microorganisms for Sustainable Agricultural Production

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Editorial on the Research Topic

Plant Growth-Promoting Microorganisms for Sustainable Agricultural Production

Global food insecurity is a chronic issue that is likely to deteriorate following climate change, rapid population growth, and the increasing scarcity of arable land. To keep up with food demand, it was seemingly necessary to increase the application of agrochemicals such as fertilizers and pesticides for improved crop production. The intensive use of agrochemicals has led to severe consequences, including soil and environmental deterioration.

Soil is heterogeneous and contains different microenvironments in each centimeter depth. Therefore, soil contains totally different kinds of microorganisms. Soil is able to shelter aerobic and anaerobic microbes, for example, in the same place and at the same moment. Additionally, soil contains microbes responsible for biochemical processes, such as nitrogen, phosphorus, sulfur, and potassium cycling.

Soil microbiomes are important because they produce essential compounds used for medicine, industry, and biotechnology.

Studies related to the soil microbiome have been deepened, and our understanding has increased. Methods using RNA and DNA, metagenomics, and metatranscriptomics have revolutionized our understanding of soil microorganisms and their potentialities.

Soils contain rhizospheric microorganisms with several abilities to promote plant growth. These abilities can affect plants directly or indirectly. The abilities that affect plants directly are related to phytohormone production, improvement of nutrient availability, nitrogen fixation, and phosphorus and potassium solubilization. The indirect effects on plant growth are biocontrol, interference of quorum sensing, and induced systemic resistance.

New methodologies have generated large soil datasets that are analyzed using algorithms and deep learning, promoting an unprecedented advance in soil microbiology.

Methodologies such as synthetic communities, SynComs, and microbiome engineering have been used to better understand the diversity and complexity of microbe-microbe and plant-microbe interactions, as well as microbial diversity and its relevance to the mechanisms of suppressing plant diseases and health and the wealth of several microbial niches in soil and its importance to diversification processes and soil bacterial genome adaptations.

This Research Topic constitutes a thorough update of the relevant topics in plant growth promotion.

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It covers all relevant topics in plant growth-promoting microorganisms, intending to provide a broad understanding of this fascinating interdisciplinary area that encompasses aspects of soil science, biophysics, ecology, physiology, genetics, biotechnology, biochemistry, and microbiology.

Msimbira et al. reviewed relevant information on the roles of plant growth-promoting microbes in enhancing plant tolerance to acidity and alkalinity stress.

Santos et al. reviewed the use of plant growth-promoting rhizobacteria in maize and sugarcane.

Mokhtar et al. showed the reduction of detrimental effects caused by salt stress on date palm by applying arbuscular mycorrhizal fungi and compost.

Hernaández-Esquivel evaluated the application of *Azospirillum brasilense* lipopolysaccharides to promote early wheat plant growth.

Chifetete et al. comprehensively reviewed mycorrhizal interventions for sustainable potato production in Africa.

Santos and Rigobelo showed some rhizobacteria isolated from sugarcane to promote its growth.

Diagne et al. evaluated the effect of plant growth-promoting rhizobacteria along with arbuscular mycorrhizal fungi on the salt stress tolerance of *Casuarina obesa*.

Diaz-Garza et al. found temporal dynamics of rhizobacteria in Pequin pepper, soybean and orange trees growing in a semiarid ecosystem.

Novinscak and Filion showed that strains of *Pseudomonas fluorescens* and *Pseudomonas synxantha* promote plant growth in talc and peat formulations.

Ochieno et al. presented a very good review of the rhizobium-linked nutritional and phytochemical changes in a multitrophic functional context in sustainable food systems.

Shahid et al. evaluated different profiles of *Bacillus* metabolites and their application in sustainable plant growth promotion and biocontrol effects.

Aguégué et al. verified the positive effects of organic fertilizer based on rhizophage intraradices for maize production.

Bal and Adhya showed the reduction of stress in rice seedlings using the rhizobacteria ACC deaminase.

Koskey et al. showed an interesting review of the potential use of beneficial microbes for soil amelioration and phytopathogen control.

Volkogon et al. evaluated the potential nitrogen fixation and denitrification in rhizosphere soil under potato cultivation and verified that this crop responded to *Azospirillum* inoculation.

Lopes et al. comprehensively reviewed successful plant growth microbes to achieve sustainable development and environmental conservation.

Gitonga et al. compared the genetic and morphological diversity of indigenous *Bradyrhizobium*-nodulating soybean in both organic and conventional production systems.

Mitter et al. approached an interesting review suggestion of a rethinking of crop nutrition in times of modern microbiology.

Araujo et al. presented interesting results of bacteria improving and modifying the essential oil rose crop.

Rivas-Franco et al. verified the biocontrol effect against *Fusarium graminearum*-producing microsclerotia from entomopathogenic fungi.

Boleta et al. verified the effect of *Azospirillum brasilense* on productivity on the nutritional accumulation of wheat cultivars.

Alberton et al. reviewed what we learned from plant growth-promoting rhizobacteria grass associations through proteomic and metabolomic approaches.

Maldonado et al. approached the importance of phosphate-solubilizing bacteria as an option for enhancing sustainable agriculture.

Cerecetto et al. showed the contrasting expression of rhizobial phytase in nodules of two soybean cultivars grown under low phosphorus availability.

Duong et al. reviewed the coffee microbiota and its potential use in sustainable management.

Díaz-Rodrigues et al. provided important knowledge about the current and future role of microbial culture collection in food security worldwide.

Molina-Romero et al. showed a bacterial consortium that interacts with different varieties of maize, promoting plant growth and reducing the application of chemical fertilizer under field conditions.

Modesto et al. showed the yield and production components of corn under the straw of Marandu palesade grass inoculated with *Azospirillum brasilense*.

Hakim et al. reviewed and gathered important information about rhizosphere engineering with plant growth-promoting microorganisms for agricultural ecological sustainability.

Yarzábal and Chica addressed microbial-based technologies for improving smallholder agriculture in the Ecuadorian Andes.

Ilangumaran et al. reported that a strain of rhizobacteria from root nodules enhanced salinity tolerance in soybean.

Ullah et al. provided important information regarding climate change and salinity effects on crops and chemical communication between plants and microorganisms.

Grover et al. reviewed PGPR-mediated alterations in root traits.

Madhaiyan et al. reported exciting results on *Burkholderia* and its interactions with some important tree species.

Romero-Perdorno et al. addressed phosphorus nutrition and plant growth in cotton crops.

Jaiswal et al. reviewed rhizobia as a source of plant growth-promoting molecules.

Diedhiou-Sall et al. verified the spatial and temporal distribution of soil microbial properties in two intercropping systems.

Scagliola et al. showed bioinoculants as a promising complement of chemical fertilizers.

Delitte et al. addressed plant microbiota beyond farming practices.

Ouverson et al. showed the temporal soil bacterial community response.

Sinong et al. reported distinct root microbial communities in nature farming.

Subramanian et al. showed thurvicin production and proteome differences in *Bacillus thuringiensis*.

Armin et al. reported an evaluation of the Apple Root-associated endophytic *Streptomyces pulveraceus*.

Ambardar et al. evaluated the diversity of the rhizo-bacteriome of *Crocus sativus* grown in various geographic locations.

Nemr et al. verified the culture media based on leaf strip root segments.

Agbodjato et al. showed the efficacy of biostimulants formulated with *Pseudomonas putida*.

Jhuma et al. isolated endophyte bacteria and showed resistance of salinity stress. Finally, Kalu et al. reviewed the response and bioremediation potential for agriculture production.

This special issue brings together many reviews and research articles focused on plant growth-promoting microorganisms and their abilities and impact on plant growth and health. Here, we summarize some of the highlights derived from the 49 articles published in this special issue.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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