applied sciences

MDPI

Editorial

Plant Growth Promoting Microorganisms Useful for Soil Desalinization

Mattia Terzaghi, Stefano Castiglione * and Francesco Guarino

Department of Chemistry and Biology "A. Zambelli", University of Salerno, Via G. Paolo II n° 132, 84084 Fisciano, Italy; mterzaghi@unisa.it (M.T.); fguarino@unisa.it (F.G.)

* Correspondence: scastiglione@unisa.it

check for updates

Citation: Terzaghi, M.; Castiglione, S.; Guarino, F. Plant Growth Promoting Microorganisms Useful for Soil Desalinization. *Appl. Sci.* **2022**, *12*, 2578. https://doi.org/10.3390/app12052578

Received: 23 February 2022
Accepted: 28 February 2022
Published: 2 March 2022

Introduction

The salinization of cultivable soils is a major issue that humankind will soon have to face. It has been estimated that around 20% of the world's land is cultivable, and over 30%, at present, is affected by salinization [1]. Moreover, it has been calculated by economists and agronomists that each year, about 10% of arable soils increase their own salt content, due, for instance, to irrigation with salted water and the use of incorrect agricultural practices, such as abundant use of mineral fertilizers [2]. Consequently, it is conceivable that in the next thirty years, more than 50% of them will be severely affected by a high salt content, causing a reduction in crop yields and also their palatability. It has been recognized that a relevant role to maintain and improve plant health is played by rhizosphere microorganisms colonizing the fine plant roots. The new-generation sequence (NGS) technique, able to sequence up to the whole genome of every kind of living being, has revealed an unknown world of microorganisms that inhabit the rhizosphere, and many of them carry out the function of plant growth promoters (PGP microorganisms), reducing either biotic or abiotic stresses, such as that caused, for instance, by soil salinization [3]. The tolerance to high salt concentrations of certain microorganism strains and their capability to improve the plant wellness have been demonstrated by several studies, also reported in this Special Issue, which, in fact, has collected papers focused on the interactions among plants and microorganisms when they are exposed to salty and/or arid soil.

In this framework, seven papers have been published meeting the interest of the readers. In particular, Castiglione et al. [4] focused their attention on the selection of novel halo/thermo-tolerant bacteria from the rhizosphere of glycophytes and halophytes, grown in compost-amended soil and watered with 150/300 mM NaCl. Beneficial effects on the biomass, well-being and resilience, exerted on the assayed crops (maize, tomato, sunflower and quinoa), were clearly demonstrated when soils were amended with 20% compost, despite the very high soil electrical conductivity (EC). The role of compost amendment was not only to provide organic matter and nutrients to plants, but also to increase the ecological resilience under salinity stress, being compost rich in halo-(4.0 M NaCl)/thermo tolerant rhizobacteria (55 °C). The authors were able to isolate 13 rhizobacteria from the plant rhizosphere, cultivated in soil amended with compost and watered with high concentrations of NaCl; some of these showed several biochemical PGP features. The key role of PGPB was also highlighted in the paper of Ferreira et al. [5]. In fact, even in this work, the authors aimed at isolating and characterizing halotolerant bacteria, associated with the rhizosphere and root tissues of *Scaevola ramosissima* (Sm.) K. Krause, envisaging their application in saline agriculture. In this case, the endophytic and rhizospheric bacteria were isolated from wild and crop-cultivated plants, growing in different estuarine conditions. The isolated halotolerant strains, belonging to the *Salinicola*, *Pseudomonas*, *Oceanobacillus*, *Halomonas*, *Providencia*, *Bacillus*, *Psychrobacter* and *Brevibacterium* genera, also exhibited several plant growth-promoting traits. These kinds of collections represent a valuable resource that can be used to optimize the crop cultivation of plants, under different environmental conditions, and for the attenuation of salt stress in non-halophytes. The role of endophytic bacteria was further developed and expounded by Gamalero et al. [6]. In their work, they isolated approximately 60 bacterial endophytes from three economically relevant plant species (cucumber, tomato and sorghum), cultivated in three different soils. Five of them were selected as plant growth promoters and were used to inoculate sorghum seeds. Following this, plant growth promotion activity was assessed on sorghum plants exposed to salinity stress. Only two bacterial endophytes increased plant biomass, but three of them delayed or reduced plant salinity stress symptoms. Interestingly, only one strain showed the ability to produce the enzyme 1-aminocyclopropane-1-carboxylate (ACC) deaminase, which is involved in the increase in stress tolerance (*Pseudomonas brassicacearum*), suggesting that ACC deaminase is not the only physiological trait involved in conferring plant tolerance to salt stress in these bacterial strains, whose physiological activities are expressed directly inside the plants, making them a powerful tool in the development of sustainable agriculture.

Considering the global threat of arable soil salinization, there is a profound interest in mitigating soil salinity that limits plant growth and productivity. In the study by Kerbab et al. [7], published in this Special Issue, eighty-nine strains were isolated from the rhizosphere and endosphere of two halophyte species (*Suaeda mollis* and *Salsola tetrandra*) collected from three chotts in Algeria. Also, in this case, the bacteria strains have been screened for diverse plant growth-promoting traits, antifungal activity and tolerance to different physico-chemical conditions (pH, PEG, and NaCl), to evaluate their efficiency in mitigating salt stress and enhancing the growth of *Arabidopsis thaliana* and durum wheat under NaCl stress conditions. Three of those were finally selected and identified as *Bacillus atropheus.* The *bacterial strains* (separately and combined) were then used for inoculating *Arabidopsis thaliana* and durum wheat during the seed germination stage, under NaCl stress conditions. The results indicated that inoculation of both plant spp. with the bacterial strains, separately or combined, considerably improved the growth parameters, proving a superior approach to increase the chlorophyll and carotenoid contents, as compared to control plants. The mechanisms involved in the mitigation of plant response to salinity stresses have been reported and explored by Shilev et al. [8], in the review titled "Plant-Growth-Promoting Bacteria Mitigating Soil Salinity Stress in Plants". The mechanisms by which to promote plant access to nutrients, or improve their growth, include phytohormone generation, the dissolution of phosphate compounds, and the production of siderophores, among others. Special attention should be paid to the modulation of plant ethylene levels by utilizing the ACC as the sole carbon source of nitrogen, due to its overall impact on plant growth and development. Regulation in plant phytohormone signaling by PGPB is a promising process for boosting the yield. In addition, the combined possession of different traits has the most noticeable positive effect on plants when subjected to the stress of salinization. Finally, Shilev suggests using a PGPB consortium, since it presents multiple traits and may have more success in real conditions, as different mechanisms can be applied. Khanghahi et al. [9] confirmed that stated by Shilev, that the use of PGPB must be considered in terms of application of bacterial *consortia.* Moreover, the study highlighted how PGPB's salinization mitigation effects can be enhanced by the use of chemical treatments (i.e., nutrient application). In fact, the benefits of durum wheat (*Triticum durum* Desf.) treatment with a *consortium* of four PGPBs is improved by the use of fertilizer, in terms of increase of the fraction of light absorbed by PSII antenna, PQ ratio and total quenching of chlorophyll fluorescence.

A second review, "Current Advances in Plant Growth Promoting Bacteria Alleviating Salt Stress for Sustainable Agriculture", by Mokrani et al. [10], was accepted to be published in the current Special Issue due to its focus on the use of PGPBs in agriculture, as a potential alternative to chemical fertilizers, biopesticides, and bioremediators under salt stress. After introducing the origins of soil salinity and its impact on crops, Mokrani showed the various roles and mechanisms of PGPBs in enhancing both the yield and growth of different plants/crops under salt stress. They recommended the use of soil autochthonous microorganisms as being more efficient in soil salinity bioremediation, with higher survival and durability in soil.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Libutti, A.; Cammerino, A.R.B.; Monteleone, M. Risk Assessment of Soil Salinization Due to Tomato Cultivation in Mediterranean Climate Conditions. *Water* **2018**, *10*, 1503. [CrossRef]
2. Brombin, V.; Mistri, E.; De Feudis, M.; Forti, C.; Salani, G.M.; Natali, C.; Falsone, G.; Antisari, L.V.; Bianchini, G. Soil carbon investigation in three pedoclimatic and agronomic settings of Northern Italy. *Sustainability* **2020**, *12*, 10539. [CrossRef]
3. Cicatelli, A.; Guarino, F.; Baldan, E.; Castiglione, S. Genetic and biochemical characterization of rhizobacterial strains and their potential use in combination with chelants for assisted phytoremediation. *Environ. Sci. Pollut. Res. Int.* **2017**, *24*, 8866–8878. [CrossRef] [PubMed]
4. Castiglione, S.; Oliva, G.; Vigliotta, G.; Novello, G.; Gamalero, E.; Lingua, G.; Cicatelli, A.; Guarino, F. Effects of Compost Amendment on Glycophyte and Halophyte Crops Grown on Saline Soils: Isolation and Characterization of Rhizobacteria with Plant Growth Promoting Features and High Salt Resistance. *Appl. Sci.* **2021**, *11*, 2125. [CrossRef]
5. Ferreira, M.; Cunha, A.; Figueiredo, S.; Faustino, P.; Patinha, C.; Silva, H.; Sierra-Garcia, I. The Root Microbiome of Salicornia ramosissima as a Seedbank for Plant-Growth Promoting Halotolerant Bacteria. *Appl. Sci.* **2021**, *11*, 2233. [CrossRef]
6. Gamalero, E.; Favale, N.; Bona, E.; Novello, G.; Cesaro, P.; Massa, N.; Glick, B.; Orozco-Mosqueda, M.; Berta, G.; Lingua, G. Screening of Bacterial Endophytes Able to Promote Plant Growth and Increase Salinity Tolerance. *Appl. Sci.* **2020**, *10*, 5767. [CrossRef]
7. Kerbab, S.; Silini, A.; Chenari Bouket, A.; Cherif-Silini, H.; Eshelli, M.; El Houda Rabhi, N.; Belbahri, L. Mitigation of NaCl Stress in Wheat by Rhizosphere Engineering Using Salt Habitat Adapted PGPR Halotolerant Bacteria. *Appl. Sci.* **2021**, *11*, 1034. [CrossRef]
8. Shilev, S. Plant-Growth-Promoting Bacteria Mitigating Soil Salinity Stress in Plants. *Appl. Sci.* **2020**, *10*, 7326. [CrossRef]
9. Khanghahi, M.Y.; Strafella, S.; Crecchio, C. Changes in Photo-Protective Energy Dissipation of Photosystem II in Response to Beneficial Bacteria Consortium in Durum Wheat under Drought and Salinity Stresses. *Appl. Sci.* **2020**, *10*, 5031. [CrossRef]
10. Mokrani, S.; Nabti, E.; Cruz, C. Current Advances in Plant Growth Promoting Bacteria Alleviating Salt Stress for Sustainable Agriculture. *Appl. Sci.* **2020**, *10*, 7025. [CrossRef]

Short Biography of Authors

Dr. Mattia Terzaghi is an Environmental and Applied Botany researcher at the University of Salerno, Italy. He received a Ph.D. in Environmental Science at the University of Insubria, Varese, Italy. His research is centred on plant roots. He studied the morphological and physiological effects of forest management on roots development, water stress resistance of Mediterranean forest ecosystems and oak seedlings with a particular attention for growth dynamics of root systems, seedling germination and growth under different light spectra, use of image analyses to measure plant traits. His current main study deal with the effects of different soil conditioners (urban compost—biochar) on olive tree growth (and their productivity) and biotic/abiotic soil characteristics.

Prof. Stefano Castiglione is Full Professor of Botany at the University of Salerno, Italy. He was graduated (1985) in Biological Science at the at the Dept. of Genetics, University of Pavia and in 1988–1990 he was postdoctoral fellow at the Enichem America's Laboratories in Princeton-NJ. During the last decade, his research activity was focused on the molecular analysis of biodiversity in species and clones of plant popultions and crops, as well as on their use for phytoremediation of inorganic and organic polluted environments. During the last years, he was also interested in the effects of fertilization with compost compared to mineral on horticultural varieties characterized by high genetic diversity. His current studies deal with the isolation and characterization of plant growth promoting rhizo-bacteria exploitable to counteract the effect of salt on plants.

Dr. Francesco Guarino is an Botany researcher at the University of Salerno, Italy. He received a Ph.D. in System Biology at the University of Salerno, Italy. His main research interests are focused on: (i) the genetic and epigenetic biodiversity studies of plant species; (ii) the phytoremediation studies to reclaim soil and water polluted by heavy metals and/or by organic emergent contaminants as pharmaceutical and personal care products (e.g., TCE, TCS, etc.); (iii) the efficacy of the physic-chemical treatments useful to inactivate antibiotic resistant bacteria strains, and to degrade their antibiotic resistant genes in the waters; (iv) the dynamics of microbial community of soil and poplar rhizosphere, in response to metal contamination and/or soil compost amendment.