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Rooted Solutions: Rhizosphere Microbiome Synergies in Phytoremediation of Contaminated Soils

Muhammad Yasir Naeem[1]*, Dilara K. Sunakbaeva[2], Yaira Rakhmetova[3], Abdol Ghaffar Ebadi[4]

[1]Department of Agronomy, Animals, Food, Natural Resources and the Environment (DAFNAE), University of Padua, Italy
[2]Faculty of Sciences, Department of Ecology and Chemistry, Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkestan, Kazakhstan
[3]Department of Biotechnology, Faculty of Biology and Biotechnology, Al Farabi Kazakh National University, Almaty, Kazakhstan
[4]Researcher and Faculty member, Jouybar branch, Islamic Azad University, Jouybar, Iran
*Presenter Author's Email: yasir.naeem91@yahoo.com

Abstract

Rhizosphere is a dynamically biological interface where plant roots intimately interact with microbes in soil and form complex synergistic interactions influencing nutrient turnover and pollutant transformation. For phytoremediation, the plant-microbiome interface is also critical in controlling contaminant bioavailability and detoxification. This review highlights recent advances in the use of plant growth-promoting rhizobacteria (PGPR), mycorrhizal fungi, and endophytes to make phytoremediation more efficient. Some functions are microbial pollutant transformation, increased root surface area, induction of stress-responsive genes, and secretion of chelating agents. Microbiome engineering strategies like inoculation with pollutant-degrading bacteria consortia or microbiome transplant from stress-resistant ecosystems are also addressed in the review. Special emphasis is placed on microbial-assisted remediation of heavy metals, hydrocarbons, and emerging contaminants like PFAS. Future directions include metagenomics and synthetic microbial communities (SynComs) to address the manipulation of rhizosphere functions. Leverage and knowledge of such subterranean partnerships can lead to ecologically safe and highly effective phytoremediation processes.

Keywords: Rhizosphere, Microbiome, PGPR, Soil remediation, Mycorrhizae, Endophytes