Microbiome-based rhizosphere engineering for mitigation of salinity stress in tomato

Salinity stress is one of the most severe environmental constraints limiting agricultural productivity worldwide. Traditional approaches for salinity management, such as chemical amendments or bioinoculant application, have provided limited and often unsustainable solutions. Against this backdrop, modifying rhizosphere microbial communities as a bio-based strategy for stress alleviation represents an emerging and ecologically sound alternative. The present study was therefore undertaken to integrate both top-down and bottom-up rhizosphere engineering approaches to establish the potential of salt stress-acclimatized rhizosphere microbiome, followed by designing a synthetic microbial community (SMC) to mitigate salinity stress and promote plant growth under saline conditions. The first phase of the study involved the acclimatization of tomato rhizosphere microbiomes by repeated transplantation across multiple plant growth cycles under the ramping up of salt concentrations. Then, the efficiency of salt stress-acclimatized rhizosphere microbiome was tested on different plant model systems. In the next phase, the bottom-up rhizosphere engineering approach was employed. The culturable bacterial isolates were recovered from the acclimatized rhizosphere, their PGP traits were characterized, and whole genome sequencing performed. Further, the untargeted metabolomic analysis of shortlisted salt stress-acclimatized bacterial strains showed strong species-specific metabolite production. Functional validation of these strains through the formation of an SMC demonstrated a synergistic effect in enhancing plant growth under salt stress. The findings confirmed that integrating both top-down and bottom-up microbiome-based rhizosphere engineering approach of designing SMC from a salt stress-acclimatized rhizosphere microbiome can yield biologically robust, ecologically stable, and functionally diverse microbial assemblages that confer enhanced tolerance to salinity stress in plants.