biofertilization, increasingly complex synthetic microbiomes, and even plant genome editing to recruit beneficial microbiota and improve resilience to drought and other stresses.

Research on rhizosphere microbial diversity in legume cropping systems has demonstrated that legumes assemble functionally specialized microbiomes with strong impacts on nitrogen fixation, nutrient cycling, and stress tolerance. Reviews of legume microbiomes highlight that rhizobia operate within broader rhizosphere and nodule communities, where non-rhizobial bacteria and other microbes contribute to nodule formation, legume fitness, and agroecosystem services, including reduced fertilizer needs and pollution. Harnessing these assemblages is therefore central to strategies aiming at sustainable intensification and climate-friendly nitrogen management.

Moving forward, realizing the full potential of legume-associated rhizosphere microbiomes will require coordinated advances from microns to field scales. Sustainable agriculture perspectives stress that exploiting nitrogen-fixing rhizobacteria and other plant growth promoters depends on overcoming challenges in bioinoculant consistency, integrating omics-based discovery with agronomy, and fostering large-scale collaboration among researchers, industry, and farmers. By combining predictive microbiome management with breeding, intercropping, and reduced-chemical inputs, legume systems can become key platforms for microbiome-based solutions that support soil health, productivity, and ecosystem sustainability.

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Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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