Bacterial social interactions in synthetic *Bacillus* consortia enhance plant growth

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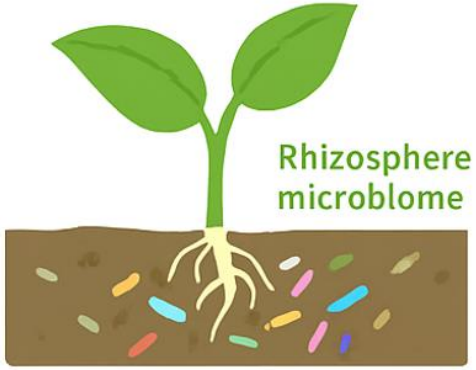
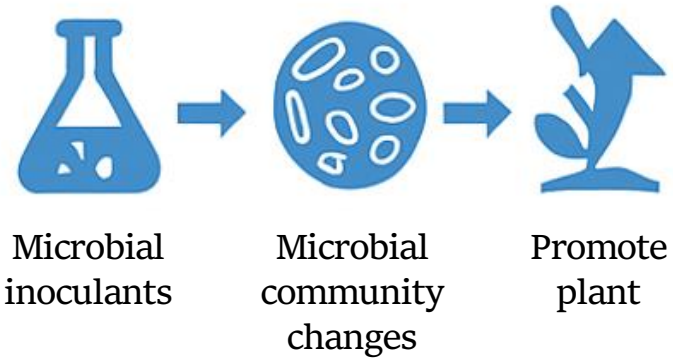
Research Background and Objectives

Importance of the plant rhizosphere microbiome



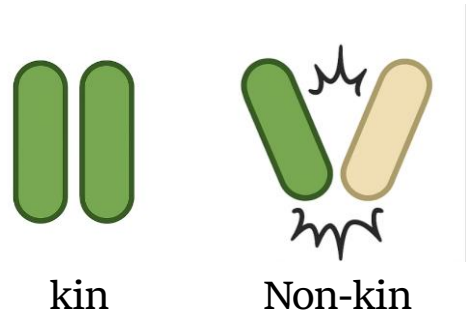
- The rhizosphere microbiome, often referred to as the plant's "second genome" plays a vital role in plant growth, nutrient uptake, and overall health.
- The plant microbiome is considered the foundation of the next green revolution.
- PGPR are widely used as microbial inoculants to promote plant growth either directly or indirectly.

Challenges and issues: limited effectiveness of inoculants



- Microbial inoculants influence the plant microbiome through various mechanisms, including modulating community diversity, suppressing pathogens, and promoting beneficial microbes.
- Their effectiveness is affected by complex microbial social interactions, especially resource competition and cooperative behaviors.
- While synthetic microbial consortia offer enhanced functionality, their stability is influenced by interactions among member strains, and effective design strategies are still lacking.

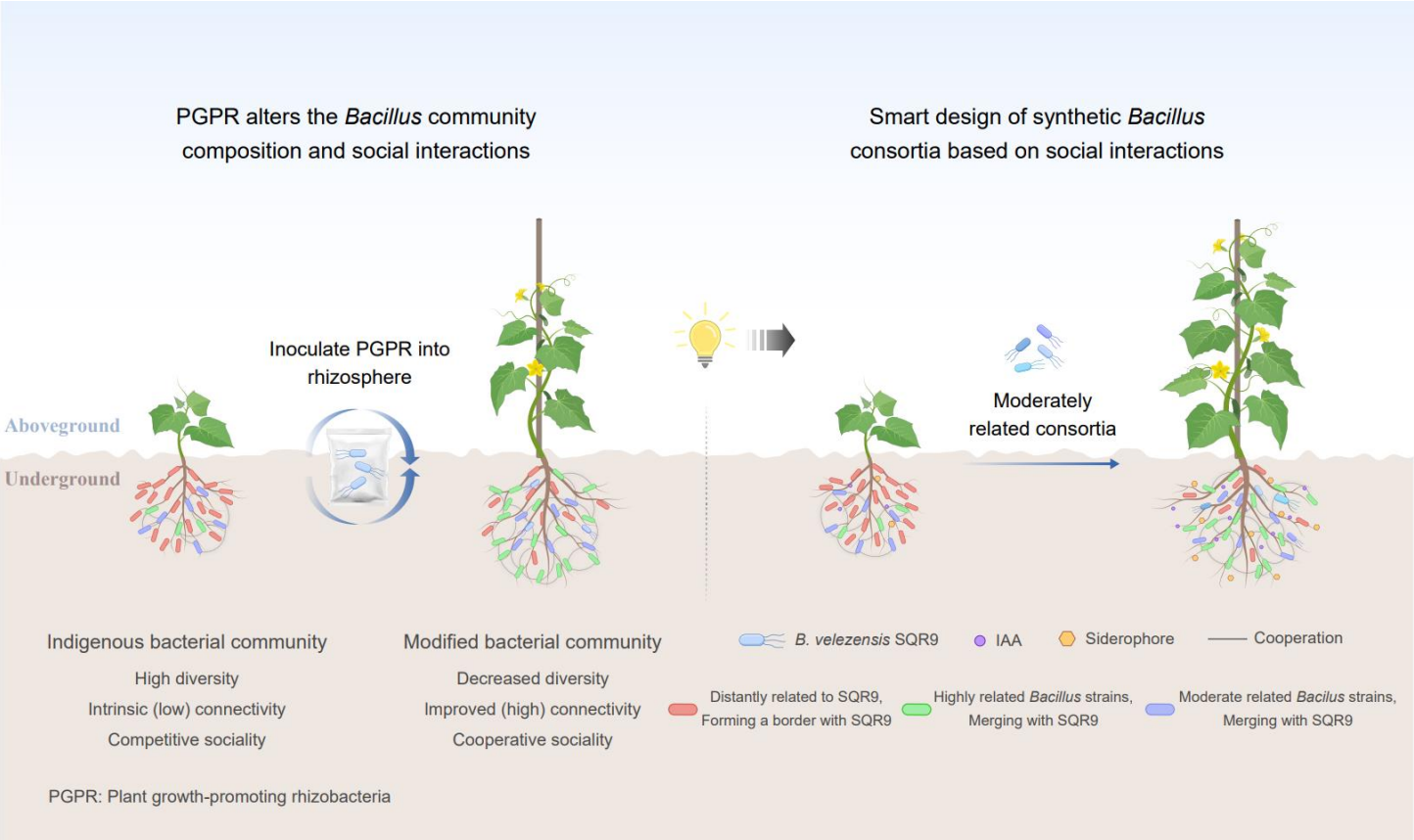
Research focus: social interactions and kin discrimination mechanisms in *Bacillus*



- The genus *Bacillus* exhibits complex social behaviors during root colonization, such as swarming and kin discrimination.
- Kin strains tend to merge and form mixed biofilms, while non-kin strains are more likely to repel each other.
- Establishing the links between community phylogenetic structure, social behavior, and plant growth-promoting functions remains a major research challenge.

Research objective: To elucidate how the PGPR strain *B. velezensis* SQR9 regulates social interactions and community functions within the rhizosphere *Bacillus* population, providing theoretical support for the ecological and rational design of synthetic *Bacillus* consortia.

Highlights



- *B. velezensis* SQR9 inoculation significantly enhanced cucumber plant growth and altered the structure of rhizosphere *Bacillus* and its related bacterial communities, promoting cooperation among closely related strains.
- Phylogenetically closer *Bacillus* strains exhibited increased social cooperation and increased metabolic niche overlap, enhancing community interactions.
- Consortia with MR strains exhibited superior plant growth-promoting effects, including increased plant height, dry weight, root colonisation, and production of IAA and siderophores.
- The study provides a framework for assembling *Bacillus* consortia with enhanced cooperation and improving the stability and effectiveness of microbial inoculants in agricultural applications.

Experimental Design

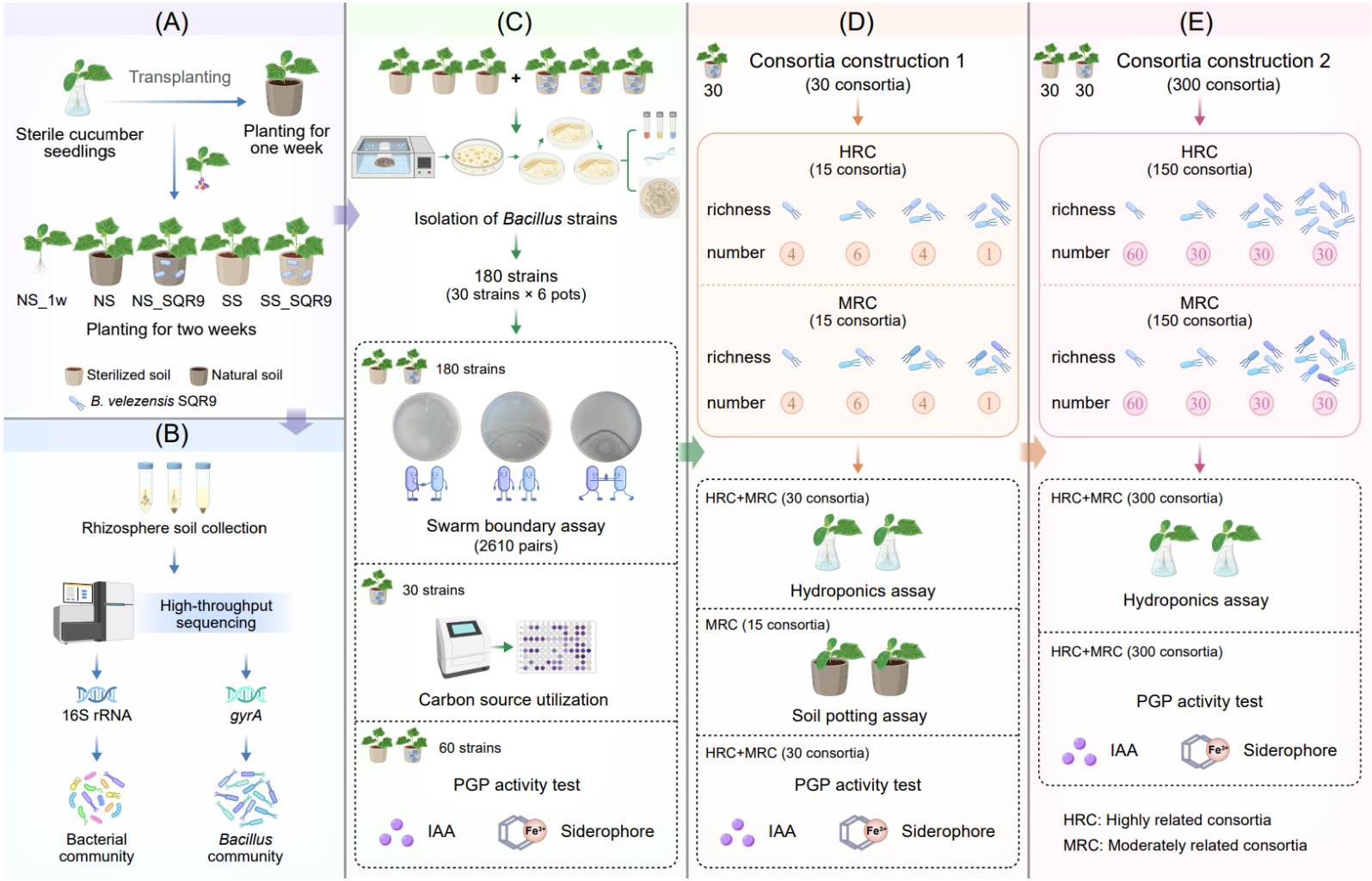


Figure 1. Experimental Design and Workflow

(A) Pot experiment; (B) High-throughput sequencing; (C) Analysis of relationships among phylogenetic relatedness, social interactions, carbon source utilization, and PGP activities of rhizosphere *Bacillus* strains; (D) Design of 30 HR and MR consortia; (E) Design of 300 HR and MR consortia. HR: High Relatedness; MR: Moderate Relatedness.

velezensis SQR9 altered the structure of the cucumber rhizosphere bacterial community

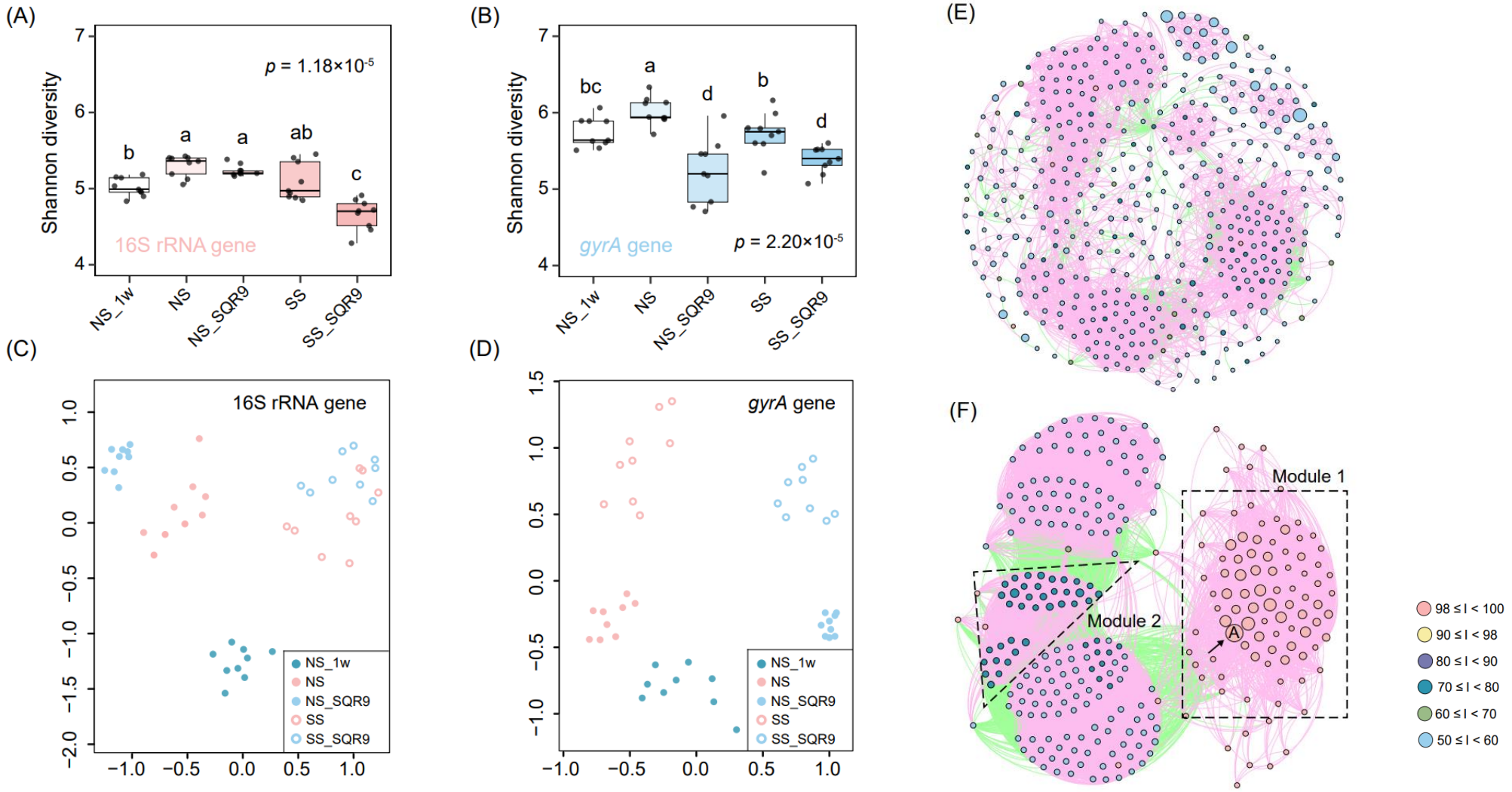


Figure 2. High-throughput sequencing analysis based on 16S rRNA and *gyrA* genes reveals the effect of SQR9 on the composition of the cucumber rhizosphere bacterial community

B. velezensis SQR9 enhances the compatibility and cooperation within the rhizosphere *Bacillus* community

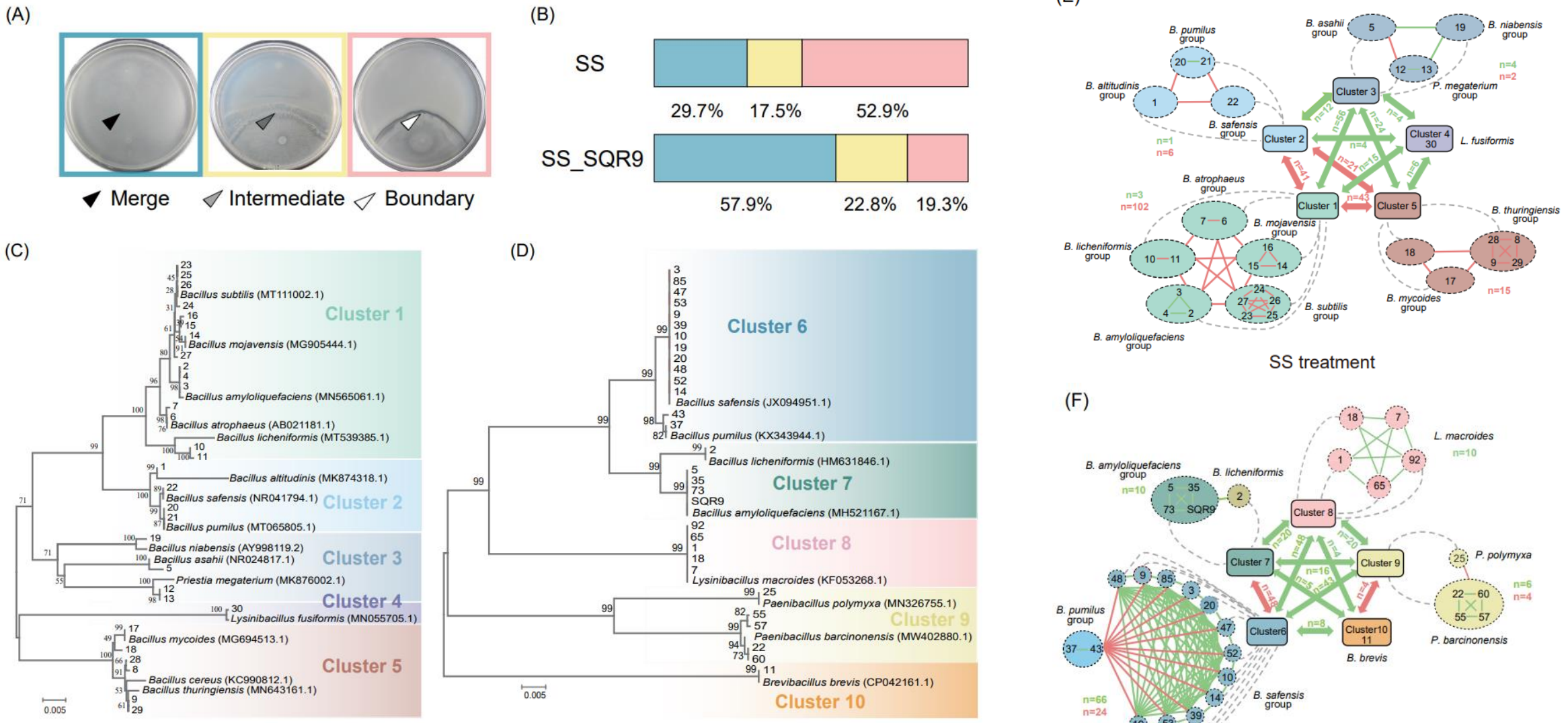


Figure 3. SQR9 alters the distribution pattern of swarming confrontation phenotypes among rhizosphere *Bacillus* strains.

Moderately related (MR) consortia promote plant growth

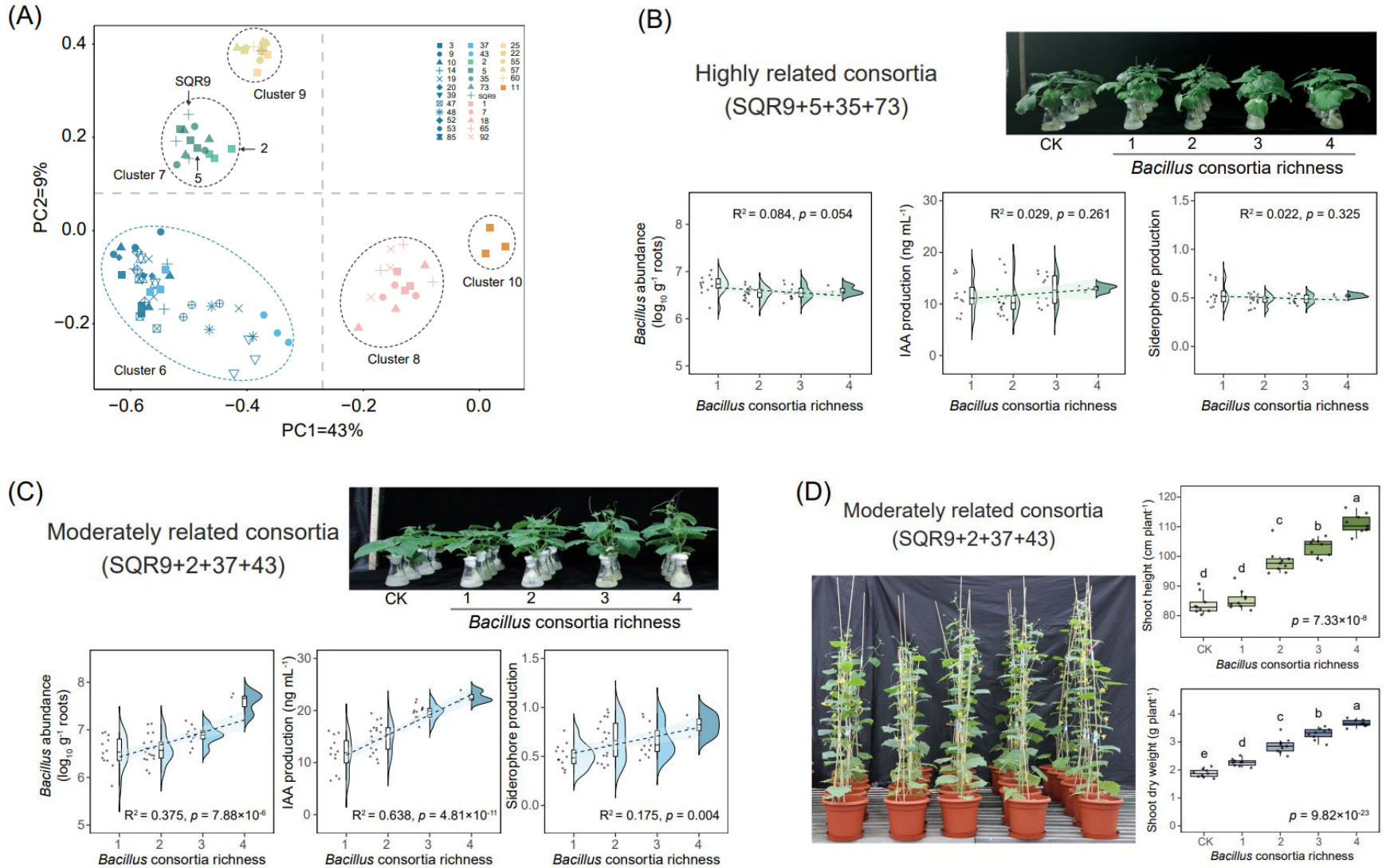


Figure 4. Importance of carbon source competition and social interactions in the rational design of growth-promoting *Bacillus* consortia

Validation of consortium design strategy through increased richness and diversified combinations

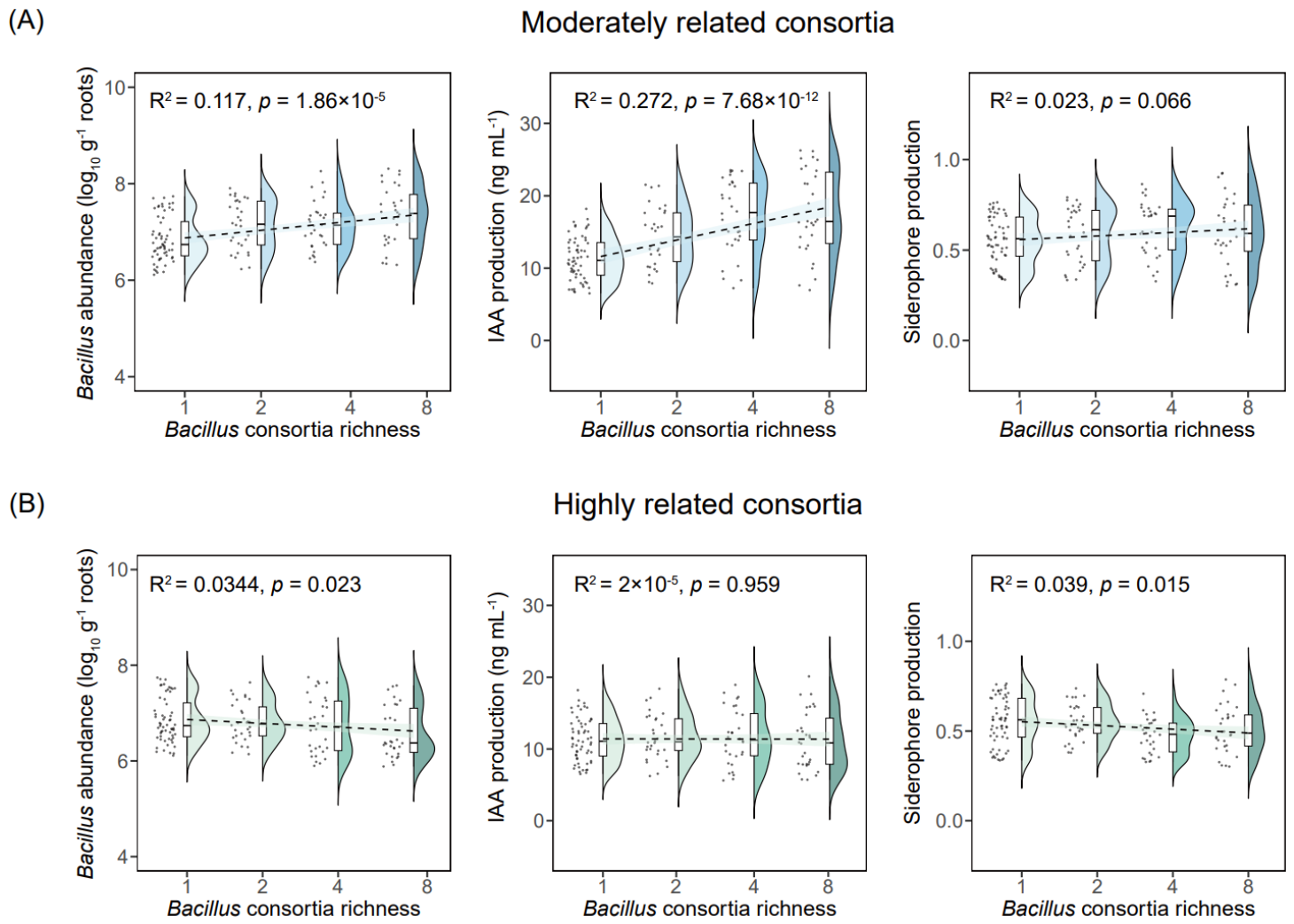


Figure 5. Expanded validation of the design strategy and construction scheme for synthetic *Bacillus* consortia based on social interactions

Summary

- This study is the first to reveal that the application of the PGPR strain *B. velezensis* SQR9 can direct the rhizosphere bacterial community—especially *Bacillus* and its related taxa—toward a more cooperative trajectory.

- Based on the regulatory effect of SQR9 on the rhizosphere microbial community, MR *Bacillus* consortia were constructed and demonstrated superior plant growth-promoting effects in both hydroponic and soil-based systems.

- This study proposes incorporating social interactions and carbon source competition into the design of synthetic microbial consortia, providing a novel ecological framework for the intelligent assembly of *Bacillus* communities and the sustainable application of microbial products.

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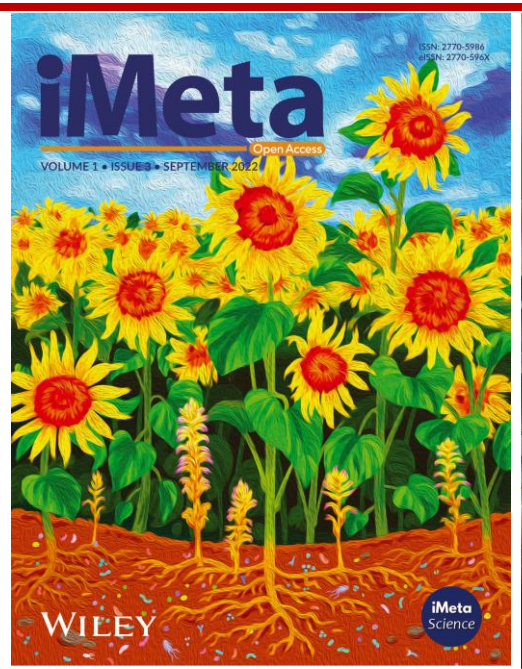

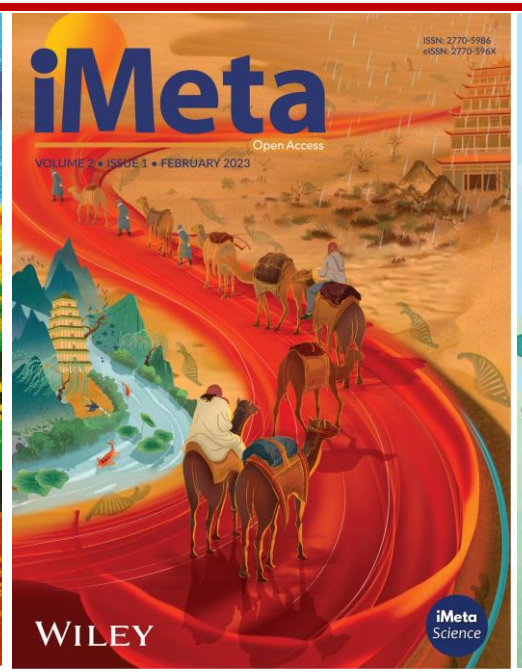

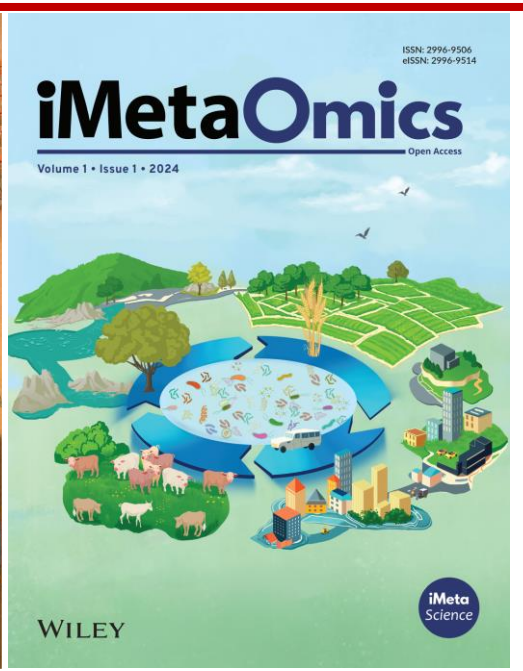

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