

6. Plant-Root Microbiota Interactions in Nutrient Utilization



(Based on Xu et al., 2025)

6.1 Root Microbiota Composition and Function

The plant root microbiota consists of a diverse collection of bacteria and fungi that colonize the root surface and surrounding soil. These microorganisms assist in nutrient uptake, protect plants against pathogens, modulate hormone signaling, and enhance the plant's stress tolerance. In essence, the root microbiota acts as an extension of the plant's own genome, significantly contributing to its overall fitness and productivity.

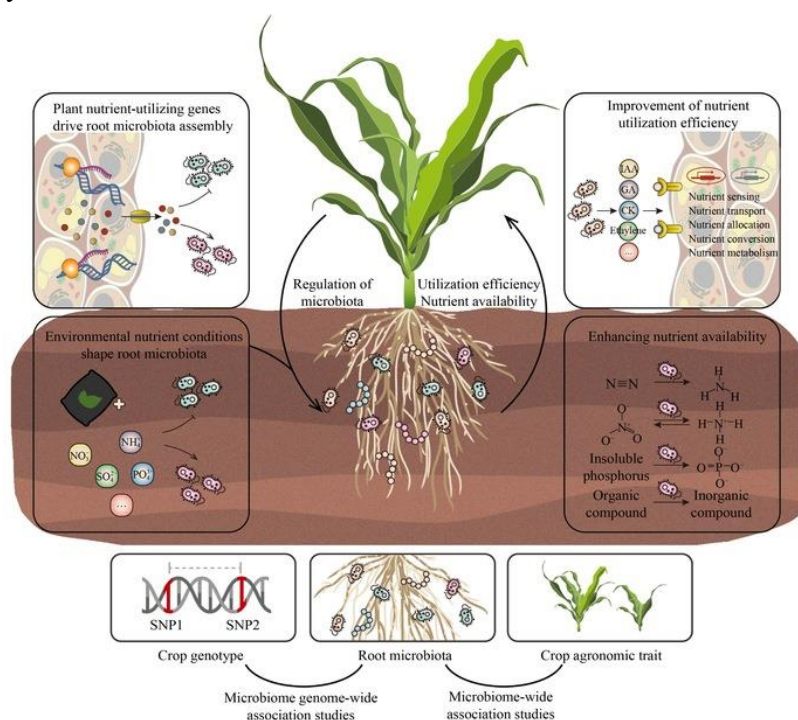


Fig. Plant and root microbiota coregulation nutrient utilization.

6.2 Factors Influencing Root Microbiota Assembly

The assembly of the root microbiota is primarily influenced by soil nutrient conditions, with availability of key elements like nitrogen and phosphorus playing a crucial role. Plant **genotype** also shapes the microbial community, especially through the expression of nutrient transporter genes that influence microbial recruitment. Additionally, root exudates and environmental factors like soil pH, moisture, and texture create specific niches that select for particular microbial populations.

6.3 Microbial Contributions to Nutrient Utilization

Root-associated microbes significantly enhance plant nutrient acquisition by mobilizing essential elements such as phosphorus, nitrogen, and iron. They employ mechanisms like solubilization, transformation of nutrients, and production of siderophores that improve nutrient availability for plants. **Moreover, some microbes can modify root system architecture, promoting greater lateral root development and thus facilitating more efficient nutrient absorption.**

6.4 Plant Regulation of Root Microbiota

Plants actively regulate the composition of their root microbiota according to their nutritional needs by altering gene expression and exudate profiles.

Example: during phosphate deficiency, plants upregulate specific transporter genes and secrete organic acids that attract beneficial phosphate-solubilizing microbes. This dynamic regulation ensures that plants can recruit the most helpful microbial partners to optimize nutrient uptake under varying environmental conditions.

6.5 Analytical Tools for Studying Plant-Microbiota Interactions

Microbiome Genome-Wide Association Studies (mGWAS) have become powerful tools for linking specific plant genetic loci to traits associated with the microbiome. Techniques like metagenomics and metatranscriptomics allow researchers to profile microbial communities and their functional activities at high resolution. Additionally, synthetic microbial communities (SynComs) are used in experimental setups to dissect the functional contributions of individual or grouped microbes under controlled conditions.

6.6 Agricultural Applications and Perspectives

Understanding plant-microbiota interactions opens exciting opportunities for sustainable agriculture by engineering beneficial microbial **consortia** to enhance nutrient use efficiency. Plant breeding programs can also be directed toward selecting varieties that naturally associate with more advantageous microbiota. These strategies could **significantly reduce fertilizer dependence, lower environmental impacts**, and help develop resilient cropping systems that are better adapted to climate challenges.

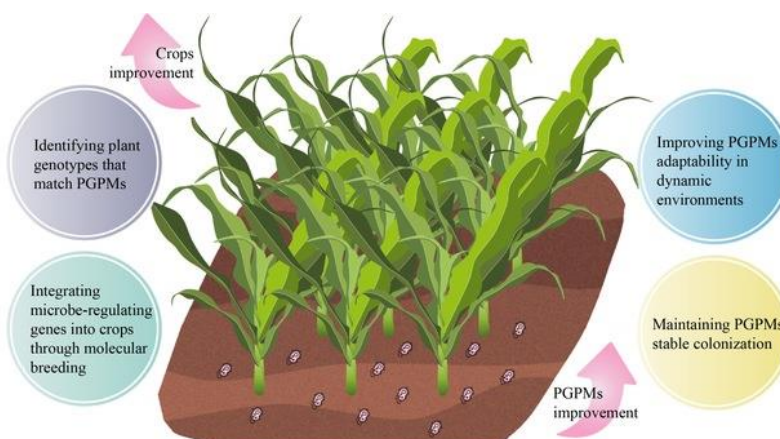


Fig. Applying root microbiota to agriculture through crops and plant growth-promoting microorganisms' improvement.

6.7 Conclusion

The root microbiota plays a vital role in supporting plant nutrition, stress resilience, and overall health. A deeper understanding of these intricate interactions offers the potential to revolutionize agricultural practices toward sustainability and resilience. Future agricultural systems are expected to integrate microbiota management and host-microbe co-evolution strategies to secure global food production.