4 Reshaping of the Rhizosphere Microbiome under Saline-Alkali Stress

4.1 Composition and ecological functions of the rhizosphere microbiome

The rhizosphere microbiome of broomcorn millet is not just a group of “associated organisms” around the root surface. It is an important ecological unit involved in adaptation to saline-alkali soils. Bacteria, fungi, archaea, and micro-eukaryotes in the rhizosphere jointly participate in organic matter decomposition, nitrogen/phosphorus/sulfur cycling, mineral activation, pathogen suppression, and root signal transmission. These functions become especially important in saline-alkali soils because high salinity, high pH, and ion imbalance reduce the availability of nutrients such as phosphorus, iron, and zinc, while also inhibiting the activity of common microorganisms. Under such conditions, microbial communities that can maintain nutrient transformation and stabilize rhizosphere metabolism largely determine whether broomcorn millet can continuously absorb nutrients and maintain growth on marginal land.

The rhizosphere microbiome is directly linked with salt-stress adaptation. Yuan et al. (2023) used the salt-tolerant variety ST47 and the salt-sensitive variety SS212 under a three-month salt-stress pot experiment. They simultaneously analyzed plant phenotype, physiological traits, microstructure, Na^+ homeostasis-related genes, and rhizosphere bacterial and fungal communities. The salt-tolerant millet not only showed better Na^+ balance and more stable tissue structure, but also reshaped the rhizosphere microbial community toward a direction beneficial for salt-stress buffering and soil nutrient cycling.

4.2 Changes in microbial communities under saline-alkali stress

The influence of saline-alkali stress on the rhizosphere microbial community of broomcorn millet is not simply a matter of “suppressing all microorganisms.” Instead, it shows clear selectivity. High-salt conditions eliminate some sensitive microbial groups while enriching functional microorganisms that can tolerate high osmotic pressure, high Na^+ concentration, and high pH conditions.

More specifically, under high salinity, bacterial groups such as Nocardioides, Saccharimonadal, and Nitriliruptoraceae become enriched in the millet rhizosphere. These groups are commonly associated with organic matter decomposition, nutrient transformation, and stress-resistant ecological niches. At the same time, fungi such as Operculomyces, Alternaria, and Cryptococcus are also enriched in the rhizosphere and may participate in organic matter degradation and nutrient absorption. Under high-salt treatment, the rhizosphere recruits these specific bacteria and fungi, which promotes soil nutrient cycling and is associated with improved nutrient uptake capacity in broomcorn millet (Chen et al., 2025).

The adaptation of broomcorn millet to saline-alkali soils does not rely only on the roots “tolerating” unfavorable conditions. Instead, the plant reorganizes the microbial community through rhizosphere selection mechanisms into a structure more favorable for nutrient supply and stress buffering. In other words, the changes in the rhizosphere microbiome under saline-alkali stress have clear ecological functions: on one hand, they reduce nutrient limitations caused by salinity; on the other hand, they improve the resilience of the rhizosphere system under unstable environmental conditions.

4.3 Beneficial rhizosphere microorganisms in broomcorn millet

4.3.1 Plant Growth-Promoting Rhizobacteria (PGPR)

Plant growth-promoting rhizobacteria are one of the most valuable microbial resources for improving saline-alkali adaptation in broomcorn millet. PGPR can promote plant growth through nitrogen fixation, phosphate solubilization, IAA production, extracellular polysaccharide secretion, siderophore synthesis, and regulation of ACC deaminase activity. Under saline-alkali stress, these functions are converted into more direct stress-resistance effects. Extracellular polysaccharides can form protective biofilms on the root surface and reduce direct Na^+ damage. ACC deaminase can lower stress-induced ethylene levels and alleviate root growth inhibition. Phosphate solubilization and siderophore production help improve the low availability of phosphorus and iron under high-pH conditions.