evaluation. Otherwise, results from different studies are difficult to compare, and application outcomes are difficult to reproduce consistently (Northen et al., 2024). For millet, future biofertilizer development should avoid the concept of "universal microbial products." Instead, it should emphasize regionalized and genotype-specific formulations. In other words, localized microbial consortia should be developed according to different saline-alkali soil types, soil textures, and millet cultivars, and their effects on yield, quality, and soil improvement should be validated through long-term and multi-location field trials.

7.5 Future role of millet in climate-resilient agriculture

The value of millet in climate-resilient agriculture comes from its multiple adaptive traits. It has a short growth cycle, high water-use efficiency, and strong adaptability to marginal lands. At the same time, it also has nutritional value, gluten-free characteristics, and potential for functional food development. Unlike major crops that depend on high inputs for high yields, millet is more suitable for low-input, low-water-consumption, risk-resistant, and diversified agricultural systems. Its role is not to replace rice, wheat, or maize, but to provide more flexible options for future food systems.

From the perspective of global agricultural trends, climate change, soil degradation, and water shortages are driving agricultural systems away from a single high-yield target toward a balance among stable production, nutritional security, and ecological sustainability. As an ancient and stress-tolerant minor cereal crop, millet deserves renewed attention in this context. Its short growth period makes it suitable for filling crop rotation gaps; its drought and poor-soil tolerance make it suitable for marginal lands; its nutritional quality supports functional food development; and the plasticity of its rhizosphere microbiome gives it potential as an important crop platform for biologically regulated agriculture.

In conclusion, the salt-alkali adaptation mechanism of millet should no longer be understood as simple physiological tolerance. Instead, it should be viewed as the combined result of plant genotype, root structure, ion homeostasis, metabolic regulation, and rhizosphere microbiome interactions. Future research should advance in three directions. First, multi-omics technologies should be used to reveal the causal mechanisms of salt-alkali tolerance in millet. Second, microbiome recruitment ability should be incorporated into breeding evaluation systems. Third, localized synthetic microbial communities and ecological cultivation technologies suitable for millet production on saline-alkali soils should be developed. Only in this way can millet evolve from a traditional minor grain crop into a strategic crop resource serving saline-alkali land utilization, food security, healthy food production, and climate-resilient agriculture.

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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