K^+, and essential mineral nutrients. Compared with major cereal crops such as maize and wheat, the value of broomcorn millet in saline-alkali land is not in forming a large vegetative body, but in achieving stable production on marginal soils through a short growth cycle and strong root plasticity.

3.2 Osmotic adjustment mechanism

Saline-alkali stress first causes a decrease in external water potential, leading to inhibited water uptake, reduced cell turgor pressure, and restricted leaf expansion in broomcorn millet seedlings. To maintain cellular water status, broomcorn millet accumulates compatible solutes such as proline, soluble sugars, and soluble proteins. The role of these substances is not simply to "increase content," but to improve osmotic adjustment capacity without significantly interfering with enzyme activity, while also stabilizing membrane structure and protein conformation.

An early study on mixed salt tolerance in 16 broomcorn millet genotypes found that under salt concentrations of 160 and 200 mmol/L, the proline content in shoots of materials such as Zhongwei Dahuangmi and Ningmi No.4 increased significantly, while the relative Na^+/K^+ ratio remained low. This indicates that osmotic adjustment and ion homeostasis together determine salt tolerance performance (Liu et al., 2012).

Octoploid broomcorn millet showed stronger antioxidant capacity under salt stress, with lower MDA content in leaves and significantly increased soluble sugar and proline content (Li et al., 2025). MDA is an important indicator of membrane lipid peroxidation damage. Its reduction suggests that the accumulation of osmotic adjustment substances is not an isolated response, but part of an integrated salt tolerance system involving membrane protection and antioxidant defense.

The core significance of the osmotic adjustment mechanism in broomcorn millet lies in maintaining cellular water status and metabolic continuity through the accumulation of small organic molecules, thereby avoiding excessive dependence on inorganic ions such as Na^+ and Cl^- for osmotic compensation and reducing the risk of ion toxicity. This is also an important reason why some tolerant materials can still recover growth after rehydration or stress relief, even though growth inhibition occurs during saline-alkali stress.

3.3 Ion homeostasis and transport regulation mechanism

For broomcorn millet, the major damage caused by saline-alkali stress is not only "water deficiency," but also excessive Na^+ accumulation and difficulty in maintaining K^+ levels. After entering cells, Na^+ interferes with K^+-dependent enzyme activity, disrupts membrane potential, and affects protein synthesis. Therefore, the key to salt tolerance in broomcorn millet is to limit Na^+ uptake, promote Na^+ efflux or vacuolar sequestration, and maintain a high K^+/Na^+ ratio. Studies on the molecular mechanisms of plant salt stress generally suggest that ion exclusion, compartmentalization, long-distance transport, and signal transduction together form the core regulatory network of crop salt tolerance (Ma et al., 2022).

A comparative study between broomcorn millet lines ST47 and SS212 provided direct evidence for this mechanism. Yuan et al. (2021) found that under 1% NaCl stress, the salt-tolerant variety ST47 maintained a better Na^+/K^+ balance and reduced toxicity by limiting Na^+ uptake, promoting vacuolar Na^+ sequestration, and enhancing Na^+ efflux capacity. KEGG pathway analysis showed that pathways related to Na^+ regulation, ion transport, and cell wall biosynthesis were significantly regulated in ST47. This indicates that salt tolerance in broomcorn millet is not simply a change in ion content, but a dynamic regulatory process involving transport proteins, signaling pathways, and tissue structure.

The adaptation of broomcorn millet to saline-alkali stress cannot simply be understood as "salt tolerance + alkali tolerance." Neutral salt stress mainly highlights Na^+ toxicity and K^+ retention, while alkali stress additionally involves the effects of high pH on root absorption, cell wall stability, and proton pump activity. As a stress-tolerant minor crop, broomcorn millet has important research value because it can reveal the special strategies used by cereal crops to maintain ion homeostasis under complex saline-alkali conditions.