3.4 Antioxidant defense system

Saline-alkali stress disturbs chloroplasts, mitochondria, and plasma membrane systems in broomcorn millet, leading to increased accumulation of reactive oxygen species (ROS). ROS are not completely harmful because they also participate in stress signal transduction. However, if they are not removed in time, they can cause membrane lipid peroxidation, protein oxidation, and cellular structural damage. Broomcorn millet maintains a dynamic balance between ROS production and scavenging by increasing the activities of antioxidant enzymes such as SOD, POD, CAT, and APX, together with non-enzymatic antioxidant components including proline, soluble sugars, flavonoids, and phenolic compounds.

Research on alkali stress showed that alkali-tolerant broomcorn millet materials possess stronger antioxidant defense capacity. Under alkali stress, the activities of antioxidant enzymes and the contents of osmotic adjustment substances in millet leaves increased simultaneously. Tolerant materials showed lower MDA content and lower electrolyte leakage rates, indicating less oxidative damage to membrane systems (Ma et al., 2021). Antioxidant defense is not simply a passive repair process after saline-alkali stress, but an active adaptation mechanism that helps broomcorn millet maintain leaf function, stomatal structure, and the integrity of photosynthetic tissues.

Studies on exogenous 24-epibrassinolide showed that hormone regulation can alleviate alkali stress injury in broomcorn millet by improving photosynthesis and antioxidant capacity (Ma et al., 2023a) (Figure 1). Exogenous treatment can regulate photosynthesis-related genes, antioxidant-related pathways, and the accumulation of effective metabolites. This suggests that the antioxidant defense system of broomcorn millet is influenced not only by stress intensity, but also by plant hormone signaling regulation.

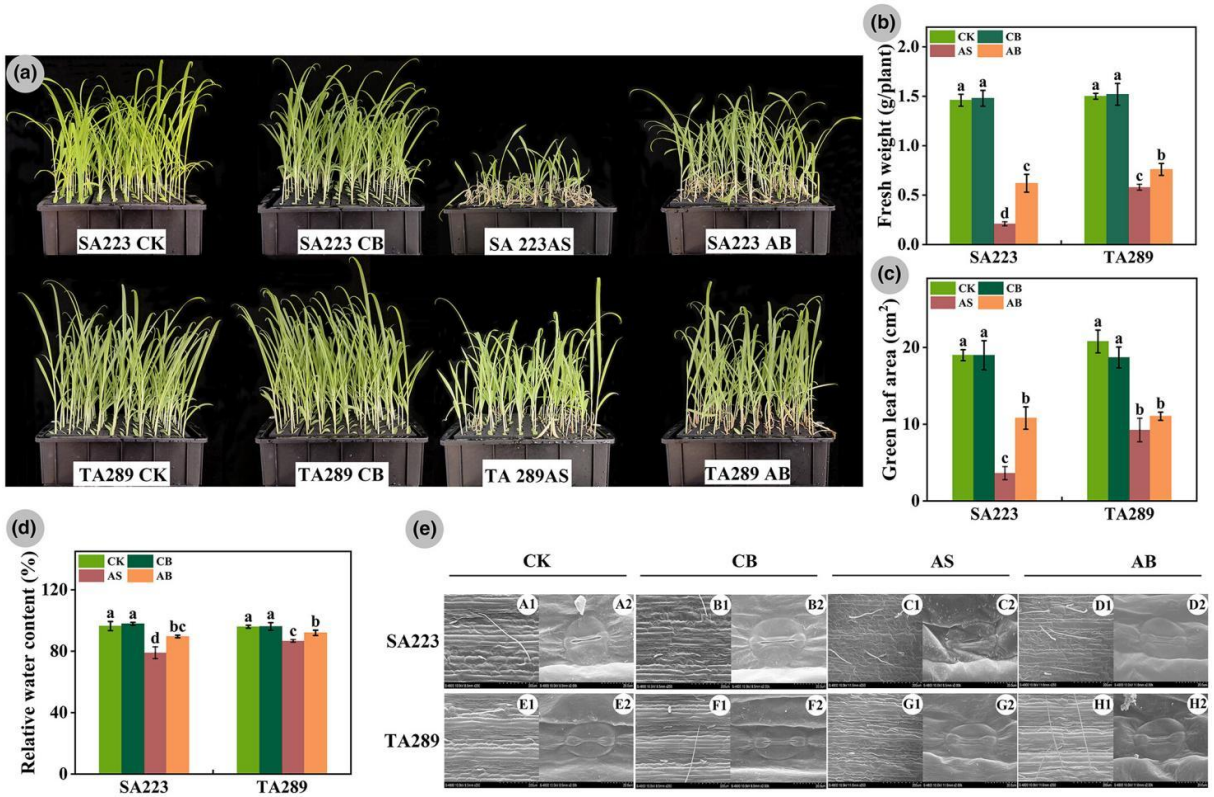

Figure 1 The growth status and leaf characteristics of SA223 and TA289 under different treatments. (a) The phenotypic differences of broomcorn millet plants grown in hydroponic culture for 7 days under different conditions. (b) The fresh weight per plant. (c) Green leaf area per plant. (d) Relative water content. (e) Scanning electron microscope of leaf surface. CK, CE, AS, and AE denote control (nutrient solution only), nutrient solution + 0.5 mg/L 24-Epicastasterone, 40 mM mixed alkali (molar ratio $NaHCO_3$:Na_2CO_3 = 9:1), and 40 mM mixed alkali + 0.5 mg/L 24-Epicastasterone. Data are mean ± standard error (n = 5). Different alphabetical letters show significant variations among the treatments ($p < 0.05$, least significant difference test). The error bars indicate the standard errors of the means (Adopted from Ma et al., 2023a)