Engineering Crops to Thrive on Sodic Lands

By YAN Fusheng (Staff Reporter)

As the world struggles with the threats of climate change and freshwater shortages, a timely breakthrough by scientists from the CAS Institute of Genetics and Developmental Biology (IGDB) and Huazhong Agricultural University provides a ray of optimism. The scientists have identified a genetic locus in sorghum, a drought-tolerant cereal grain, that can be modified to enhance alkaline tolerance in various monocot crops. This pioneering work, which could transform millions of hectares of sodic lands into arable farmland, represents a significant stride towards ensuring global food security amidst environmental challenges.

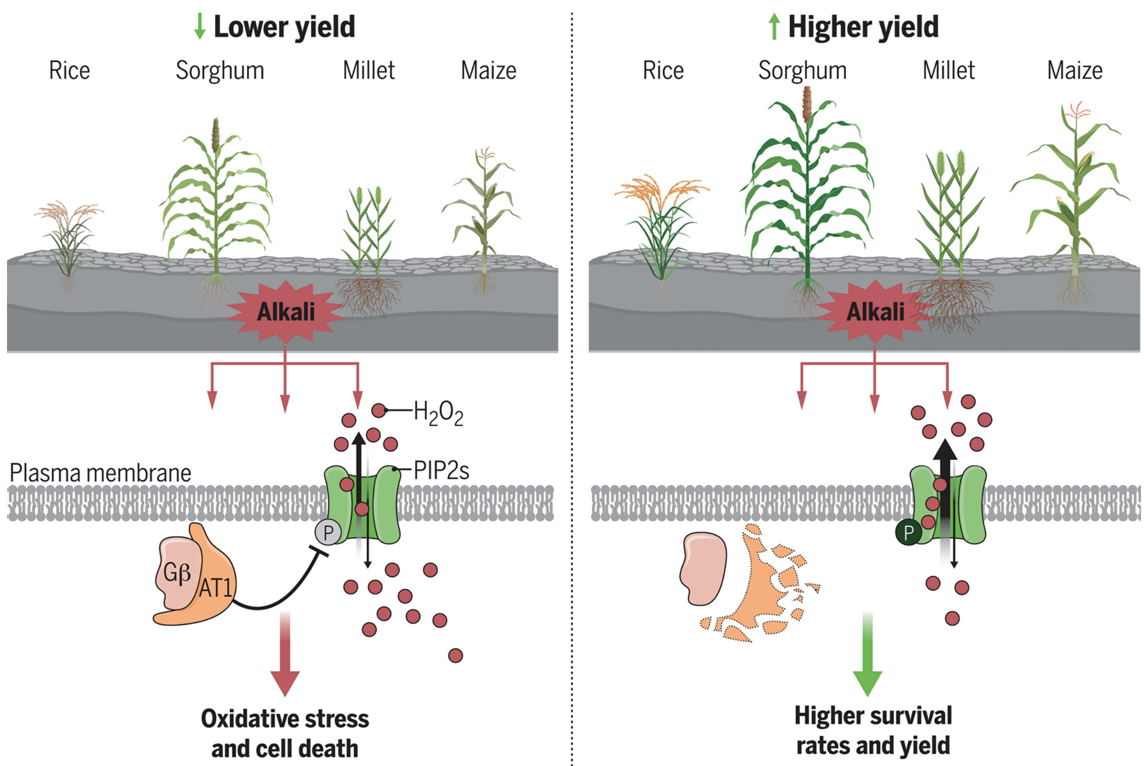
Sorghum, a grain that originated in Africa, can endure the harsh environments of highly alkaline soils where many other crops cannot. Here, scientists uncover how sorghum plants thrive on sodic lands. (Image created by Midjourney)

In the face of escalating climate change and the ever-increasing scarcity of freshwater, more than half of the world's arable land is projected to succumb to salt by 2050, warns the Food and Agriculture Organization of the United Nations. However, a groundbreaking discovery offers a beacon of hope – scientists have discovered a promising way to engineer crops that can thrive in such sodic soil, a type of soil dominated by sodium bicarbonate and sodium carbonate.

In a recently published study in *Science*, a collaborative team, spearheaded by Dr. YU Feifei and Dr. XIE Qi from the Institute of Genetics and Developmental Biology (IGDB) under the Chinese Academy of Sciences, in conjunction with Dr. OUYANG Yidan from Huazhong Agricultural University, have pinpointed a genetic locus in sorghum that plays a crucial role in its sensitivity to alkaline, salty soils. The team also showcased that by modifying this particular locus, the ability of alkaline tolerance in a variety of other crops can be significantly enhanced. This pioneering discovery paves the way for agricultural expansion into the millions of hectares of sodic lands previously deemed unsuitable for cultivation.

Sorghum is an ancient cereal grain that belongs to the grass family *Poaceae*. The hearty, drought-tolerant plant has been cultivated as a staple food for a few thousand years in many parts of the world, especially in Africa. It's like the Hulk of the plant world, its strength stemming from a specific genetic locus the researchers have identified, known as *Alkaline Tolerance 1* (*AT1*).

But how does this piece of genetic jigsaw fit into the bigger picture? Digging deeper, the researchers found that *AT1* interacts with a group of proteins known as aquaporin PIP2s, which play a crucial role in the regulation of reactive oxygen species (ROS) homeostasis. More specifically, AT1 encodes a unique G protein γ subunit that influences the phosphorylation of aquaporins, thereby modulating the distribution of hydrogen peroxide (H_2O_2). These intricate processes seem to safeguard plants from the oxidative stress induced by alkaline conditions.



Genetic modification of AT1 enhances alkaline stress tolerance. AT1 protein works with Gβ to limit PIP2 aquaporins, channels that can transport hydrogen peroxide to alleviate oxidative stress, reducing their H_2O_2 release and causing an excess of H_2O_2 that makes plants more sensitive to alkaline stress. However, crops with dysfunctional AT1 lift this limitation on PIP2s, boosting H_2O_2 efflux and enhancing survival and yield under alkaline conditions. (Image by ZHANG *et al.*/*Science*)

In detail, aquaporins act as the cell's pumping system, regulating water and hydrogen peroxide flow. When *AT1* interferes with them, it slows the efflux of H_2O_2 and gets intracellular H_2O_2 level building up. As a result, it increases the plant's oxidative stress that can cause damages to cellular proteins, lipids, and DNA. In a simpler term, *AT1* works as a negative regulator on aquaporins.

Field tests in a number of monocot crops (sorghum, rice, maize, and millet) solidified the lab's findings. Crops with the nonfunctional *AT1* mutation, both naturally occurring and engineered, showed significant improvement when grown on sodic lands. The team expects that these findings will contribute to maximizing the usage of global sodic lands to ensure future food security.

Expanding this discovery to dicotyledonous crops like tomatoes, potatoes, and fruit trees may appear straightforward. However, researchers urge caution as the homologs of *AT1* locus in the dicots have been reported to play opposite roles.

Reference

Zhang, H., Yu, F., Xie, P., Sun, S., Qiao, X., Tang, S., . . . Xie, Q. (2023). A Gγ protein regulates alkaline sensitivity in crops. *Science, 379*(6638), eade8416. doi:10.1126/science.ade8416