Salt Stress

and salinity is inherent in important strategies to this end and (2) is a more rational and sustainable use of natural resources, land, and water is therefore essential to reverse the degradation of the environment and to ensure sustained productivity.

Meeting current and future food demands necessitates a short-term increase in food production in both irrigated and rain-fed lands, including those areas where poor production in both irrigated and rain-fed lands, indicating these areas merit high salinity in agricultural soils has been

Salt flat in Utah, United States

References

Development of Salt-Tolerant Crops by Conventional Breeding

The existence of plants that thrive in soils with high levels of salts (termed halophytes), and the occurrence of variation between crop cultivars in salt sensitivity, indicate that salt tolerance is to a large extent under genetic control. Halophytes represent only about 2 percent of plant species, however, they can be found among half of the terrestrial plant families and are very variable and diverse. Although the development of tolerance to salt is believed to have occurred independently several times during the evolution of land plants, halophytes seem to have evolved the same basic method for dealing with salinity: storing harmful salt ions in the cell vacuole and accumulating organic solutes (which act as osmoprotectants) in the cell cytoplasm (6).

Conventional breeding requires the identification of genetic variability to salinity among different varieties or cultivars of a crop, or in sexually compatible species, and breeding this tolerance into lines with suitable agronomic characteristics. Conventional breeding programs for salinity tolerance include the development of rice, wheat and Indian mustard varieties tolerant to salt and to alkali soils by the Central Soil Salinity Research Institute in Karnal, India (7) and efforts to incorporate salt tolerance to wheat from wild relative species (8). A number of genomic tools, such as molecular markers and gene profiling methods, can greatly improve the efficiency of breeding programs, and should be fully exploited for conventional breeding initiatives.

Engineering Salt-Tolerant Crops by Genetic Modification

Although not a crop plant, Arabidopsis has played a vital role in the elucidation of the basic processes underlying stress tolerance, and the knowledge obtained has been transferred to a certain degree to important food plants (4). Several features make Arabidopsis an ideal model organism: a small fully-sequenced genome, a small size, and a short life cycle. In addition, a wealth of genomic resources is available for Arabidopsis, and insights gained can be used to improve our understanding of the same processes in crop plants, which are less amenable to genetic studies. Many of the genes known to be involved in stress tolerance have been isolated initially in Arabidopsis.

Mutant analysis— the screening for mutations that affect the plant’s response to stress— has been a crucial tool in the discovery of genes acting in the network. Screens designed include those aimed to identify mutations with increased or decreased sensitivity to drought, salinity and cold stresses. Also important has been the use of DNA microarray technology, which allows monitoring changes in gene expression in response to stress, and to identify genes that are either induced or repressed by the treatment (5).

The development of salt-tolerant crops by genetic engineering have focused on the following strategies: increasing the plant’s ability to limit the uptake of salt ions from the soil; increasing the active extrusion rate of salt ions; and improving the compartmentalization of salt ions in the cell vacuole where they do not affect cellular functions. Genes encoding osmoprotectants have also been the targets of genetic modification experiments, but although their over-expression in some cases improves salt tolerance, in general they also affect plant growth in the absence of stress with negative effects in yield, a highly undesirable trait for farmers (2, 9).

Salt intake is controlled by low and high affinity ion transporters: trans-membrane proteins that move ions across the cell membrane, which are also required for the intake of potassium ions (K+). The efflux of ions from the plant depends on the activity of the SOS1 gene (Salt Overly Sensitive1), initially characterized in Arabidopsis but recently identified in rice, and shown to be functionally conserved between dicots and monocots (10). Vacuolar membrane transporters, including the one encoded by AtNHX1 gene of Arabidopsis, play a role in the sequestration of ions into the vacuole. NHX1 proteins are also conserved across species, and have been isolated from several crops. Over-expression of NHX1 genes in Arabidopsis, rice, canola and tomato have been reported to increase the tolerance to salt stress (3).

Conclusion

Salt tolerance is a very complex trait, both at the physiological and at the genetic levels, and is also very influenced by other environmental factors acting on the plant at the same time. In addition, the genetic control to salt stress differs in different stages of the plant’s life cycle: tolerance at the adult stage does not necessarily correlate with tolerance at the seedling and juvenile stages, or to the ability to germinate in the presence of salts (2, 9). Rice, for example, is much more affected in grain filling than in vegetative growth by the presence of salt in the soil. To complicate matters further, it is very difficult to design field trials to test the agronomic performance of improved salt-tolerant varieties, as the salt concentration in soils is very variable, and is complicated by the presence of additional pollutants and inland water intrusion.

Plant genomes need to be very plastic, a feature required to cope with a variable environment that requires a constant adjustment of the plant’s metabolism. It is therefore essential to test newly developed stress-tolerant varieties to multiple stresses in laboratory conditions, and the importance of carrying out extensive field studies in a large range of conditions that assess tolerance as absolute yield increases cannot be over-emphasized (11).