Review: Effects of Soil Salinity on Plant Growth

Salt stress is one of the major abiotic threats to plant life and plant agriculture worldwide and significantly reduces crop yield in affected areas. Excessive salt above what plants need limits plant growth and productivity and can lead to plant death. About 20% of all irrigated land is affected by soil salinity, decreasing crop yields (Kader, 2010 March). Plants are affected by salt stress in two main ways: osmotic stress and ionic toxicity. These stresses affect all major plant processes, including photosynthesis, cellular metabolism, and plant nutrition. This paper examines the ways in which salt inhibits plant function and the correlating responses of plants to salt stress. Plants can be divided into two categories in regards to salt stress: glycophytes and halophytes. Glycophytes are extremely sensitive to salt in soils; halophytes are salt tolerant and often grow in salty environments. Glycophytes comprise the majority of plant life and all major crops, so the increasing salinity in soils is of major concern.

Soil Salinity

Soil salinity occurs naturally in sea salt marshes or areas in which salt is already a part of the soil composition. This is called primary salinization, and any plants that grow here are adapted to the soil composition. Secondary salinization occurs when soils that once had a low concentration of salt become saltier because of irrigation and poor drainage (Zhu, 2007). The plants that grow on these soils are not adapted to tolerate salty conditions, thus, when soils become more saline, they struggle to thrive. Salts can also result in the deterioration of soil structure and a decreased capacity to hold water or aerate. Ideally, farmers should use fresh water to irrigate fields in arid regions, but because of the demand for fresh water in many other sectors, growers use water with a higher salt content such as ground water, drainage water, or treated wastewater (Yadav et al., 2011). The cations and anions correlated with salinity are Na+, Ca2+, Mg2+, Cl−, SO42−, and HCO3− (Yadav et al., 2011). Excessive sodium and chloride ions are toxic to plants.

Effects on plant water uptake and ion homeostasis

Salt has two major effects on plants: osmotic stress and ionic toxicity, both of which affect all major plant processes (Yadav et al., 2011). Plants are able to take up water and essential minerals because they have a higher water pressure than the soil under normal conditions. When salt stress occurs, the osmotic pressure of the soil solution is greater than that in plant cells. Thus, the plant cannot get enough water (Kader, 2010 March). In addition, its cells will have decreased turgor and its stomata will close to conserve water. Stomatal closing can lead to less carbon fixation and the production of Reactive Oxygen Species (ROS) such as superoxide and singlet oxygen. ROS disrupts cell processes through damage to lipids, proteins, and nucleic acids (Parida and Das, 2005).

Ionic toxicity occurs when concentrations of salts are imbalanced inside cells and inhibit cellular metabolism and processes. Sodium ions at the root surface disrupt plant nutrition of the similar cation potassium by inhibiting both potassium uptake and
enzymatic activities within the cell. Potassium is an important nutrient in a plant, regulating over 50 enzymes (Kader, 2010 March). Essential for maintaining cell turgor pressure, creating membrane potential, and regulating enzymatic activities, potassium must be maintained at 100-200 mM in the cytosol. Sodium, on the other hand, causes stress at concentrations higher than 10 mM in the cytosol (Kader, 2010 March). Na⁺ is a cation similar to K⁺ and easily crosses the cell membrane. It also acts as an inhibitor to many enzymes, affecting metabolic processes.

Calcium cations, however, protect some plants through signaling pathways that regulate potassium sodium transporters (Parida and Das, 2005). When a plant senses salt stress through transmembrane proteins or enzymes in the cytosol, the amount of calcium in the cytosol increases (Kader, 2010 March). Calcium is a second messenger important to many biochemical pathways and can aid plants in responding to salt stress.

The osmotic and ionic stress induced by salinity can halt plant growth as the plant focuses its energy on conserving water and improving ionic balance. In order for plants to return to normal functioning and photosynthesis, the plant must facilitate its own detoxification – damage must be prevented or lessened, homeostasis must be re-established, and growth must resume (Zhu, 2001).

**Glycophytes**

Glycophytes comprise the majority of all plant life, including important economic and food crops. Glycophytes cannot tolerate salt stress, though they can develop protective measures against it. These plants are extremely sensitive to salt concentrations – inhibition or death can result from 100-200 mM salt. Fruit trees, such as citrus and avocado, are even more sensitive, requiring soil below a few millimoles per liter of NaCl (Zhu, 2007). Salinity affects seed germination as well as normal plant processes in a growing plant (Malcolm et al., 2003).

Glycophytes cannot be said to have salt tolerance; instead, they have salt resistance mechanisms. Glycophytes cope to a point by creating a high K⁺/Na⁺ ratio through active ion transport, shifting ionic and electrochemical gradients to be more favorable to cytosolic processes (Yadav et al., 2011). Salt accumulates in the reproductive organs and the leaves, and the plant focuses on mere survival rather than growth or reproduction (Zakharin and Panichkin, 2009).

*Arabidopsis thaliana* is a model glycophyte that has allowed researchers to better understand salt resistance in glycophytes on a genetic, cellular, and whole plant level (Zhu, 2001). However, there is not much glycophytes can do in order to adapt to salty conditions; research is being done into transgenic plants that utilize genes from halophytes to increase salt tolerance in a glycophyte. In order to combat the negative effects of salt stress on glycophytes, soil salinity must decrease or glycophytes must slowly adapt through natural processes or anthropogenic breeding or genetic modification (Zhu, 2001).

**Halophytes**

One percent of plants are halophytes and can tolerate levels of salt concentration anywhere from 300-1000 mM of salt (Zhu, 2007). The major important differences in halophytes are their abilities to compartmentalize sodium and accumulate osmolytes while maintaining constant potassium concentrations. They can accumulate more salt in leaves and roots, and can force sodium across the tonoplast with highly Na⁺/K⁺ selective protein transporters (Radyukina et al., 2007). Most halophytes respond to
salinity by exclusion (Yadav et al., 2011). In mangroves, 99% of salts are excluded by the roots (Aslam et al., 2011). Even so, plants must take up salt under salt stress and store it in vacuoles or tissues where its damage is least or secrete. Secretion occurs through shedding of salty leaves and also through salt glands, specialized cells on the leaves and stem that secrete salt, which is then washed away by rain or wind (Aslam et al., 2011).

Halophytes and glycophytes share some similar genes, and some of the genes glycophytes express under salt stress are always expressed in halophytes (Radyukina et al., 2007). In halophytes, gene expression includes the LEA protein, enzymes for biosynthesis of osmolytes, transporters for ions, and regulatory molecules like protein kinases and phosphatases (Aslam et al., 2011). Of particular importance is the synthesis of osmolytes. Osmolytes are low molecular weight compounds that do not interfere with normal biochemical reactions, but do help maintain a water potential more negative than the soil so that water uptake can take place (Parida and Das, 2005). For example, gene expression is responsible for higher levels of the osmolyte proline in Thellungiella halophila, the model halophyte organism (Kant et al., 2006). Halophytes also have a mechanism for scavenging Reactive Oxygen Species and eliminating them (Parida and Das, 2005).

Transgenic traits from halophytes could be used in glycophyte crops in order to increase salt tolerance, specifically, inserting genes that regulate the production of osmolytes in the cytosol to re-establish an ion gradients and electrochemical gradients (Zhu 2001).

**Conclusion**

To summarize, salt stress in plants is of growing concern in agriculture but has effects on many different plants and ecosystems. It induces a water deficit and ionic toxicity in plants, causing major plant processes like photosynthesis and metabolism to slow or halt. Halophytes and glycophytes deal with salt stress differently, and glycophytes do not have a mechanism for salt tolerance. Because glycophytes are essential to food supply, researchers are seeking ways that halophytes could be adapted for food or used to increase salt tolerance in glycophytes.
LITERATURE CITED


