Plant Biology

How plants protect themselves from salt stress

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ABSTRACT

Salt stress triggers a series of responses in plants, necessary to resist to this life-threatening condition. We found that one of these responses consists of modifying RNA molecules making them more resistant to degradation. These findings may provide useful approaches for engineering salt-resistant crops

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We often think of genes as a static piece of information in DNA that determines different physical aspects of life. I have blue eyes because I have the gene(s) for blue eyes. However, while DNA is important in determining such features, it's the proteins encoded in the genes that have the ultimate ability to influence physical traits. As each gene within DNA is a blueprint for the proteins, how do we go from DNA to protein, from blueprint to machine? Messenger RNA (mRNA) serves as the intermediate molecule between DNA and protein. mRNA, a temporary copy of the genic portions of DNA, delivers the gene information to the ribosome: the center for protein production in a cell. An RNA molecule is made up of a sequence of four bases (like DNA): adenine (A), uracil (U), cytosine (C), and guanine (G), and is usually derived from a single gene and therefore contains the blueprint for a single protein, mailed out straight from the DNA post office.

As you may also have experienced with the postal service, many designations such as 'airmail', 'priority', or 'return to sender' are used to ensure that mailed items arrive at their correct destinations on time. Similarly, mRNA can be labeled, processed, and shipped for protein production, or destroyed in a variety of ways before being used to make proteins. Recently, there has been interest in characterizing the role of a small 'stamp' that is placed on many mRNAs where a tiny chemical modification is added to a specific location on adenines ('A's) found within these molecules. This chemical modification known as 'N^6-

methyladenosine' (m^6A) is found in the majority of mRNA molecules, yet what this tag does to regulate the fate of these molecules in plants is still unclear.

In order to answer this question, we took healthy genetically 'normal' (wild-type, in genetics vocabulary) plants and mutant plants that were incapable of adding this m^6A mark to mRNAs. We then sequenced all of the mRNAs in both types of plants. Our sequencing experiments showed us that mRNAs in wild-type plants that contained m^6A were far more abundant when compared to the same mRNAs in mutant plants lacking this chemical tag. When we investigated further, we noticed that in mutant plants these mRNA molecules were cut right before where the m^6A modification should have been, based off our observations of where m^6A occurred in wild-type plants. We were curious to see whether there was a particular set, or sets, of genes that were being cut and destroyed in m^6A deficient plants, and we found that many genes involved in plant salt stress response were being mis-regulated in the absence of m^6A modifications.

This finding led us to hypothesize that this m^6A modification may serve to protect mRNAs from degradation. This in turn leads to the production of the proteins encoded in these mRNAs, which help plants to respond to stressful salt-rich environments that would be otherwise potentially fatal. Salt is a common agricultural stress, especially due to irrigation. As water from irrigation evaporates, salt remains, leading to an accumulation of salt in soils over time. In order to test whether the m^6A modification served to facilitate this response to salt stress in plants, we characterized the landscape of mRNAs in plants that were watered under normal conditions as well as plants that were subjected to salt stress by watering with saltwater. What we observed was that plants that were subjected to the salt treatment started to add m^6A modifications to mRNAs. We saw that these molecules were protected from being internally cut and destroyed, presumably leading to increased protein output of these genes. In the absence of salt treatment, these same mRNAs, were not marked with m^6A and were thus subjected to internal breaking and degradation. That is, this m^6A protection of mRNAs allows plants to respond to salt stress.

Over the course of this study we characterized a novel molecular mechanism that plants use to respond to salt stress. When the need arises, plants are able to protect mRNAs important for salt response by adding this small m^6A tag, shielding these mRNAs from internal breaking. In the absence of this stress, these molecules remain unprotected as they are unnecessary. This novel mechanism provides useful approaches for engineering salt resistant plants that will yield higher crop production in a future with increasingly saline farmland.