The crisis management system of plants responding to environmental changes

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[About my research]

In recent years, Japan has been hit by frequent heat waves, heavy rains, typhoons, and earthquakes, and various natural disasters have occurred throughout the Japanese archipelago. I express my deepest sympathies to all those affected. Different infrastructures and houses were severely damaged, and so did fields, forests, and coastal areas, which support daily human life.

Figure 1 Nazuna plant (*Capsella bursa-pastoris*) growing in Rikuzentakata City one year after the Great East Japan Earthquake.

I found a plant under my feet (Photo 1) when I visited the disaster site. When we look at each of the plants around us, they seem very weak. Come to think of it, it has been 450 million years since plants first appeared on land. During that time, plants have continued to survive even in the face of significant climate changes that caused the extinction of dinosaurs and other animals. Plants have differentiated and adapted to various climates. Plants came to live on land and extant ones have survived up to our age by securing water and competing with significant temperature changes. And they have been provided food for animals and us humans.

Our studies have been conducted on how plants on how development proceeds by regulating expression of various genes. Also, we have conducted studies of how plants switch genes on and off in response to different environmental changes. When we grow plants by our hands, we try to protect them somehow so that they can grow peacefully. In fact, plants are not fragile; when environmental changes occur in wild nature, plants do not immediately die but instead respond in some way on their own to survive. When the growing environment becomes unfavorable during development or growth, plants often change their gene expression patterns. For example, it is well known that young plants that have sprouted in the shade of other plants will try to get to the sun early and accelerate stem elongation. I am interested in these potential adaptability by modulating gene expression patterns in plants. I would like to know the as yet unknown gene expression patterns that plants have for crisis management. Such knowledge must be meaningful for sustainable agriculture and forestry and for learning the key to instructing organisms and humans how to live in the global environmental changes that may occur.

When plants are exposed to higher-than-normal temperatures, they exhibit different gene expression patterns than they did before. I am interested in the meaning of such new expression patterns against the tolerance to high temperatures (biological meaning for survival) and how they dynamically change their gene expression patterns (crisis management system for survival). Plants generally have about 25,000 ~ 50,000 protein-coding genes. Exposure to high temperatures can cause to increase of over a thousand genes' expression with simultaneous decrease of nearly the same number of genes' expression. This cannot be explained by the increased transcription initiation alone, which increases expression. It is also necessary to suppress the expression of genes that were expressed before the environmental change and are "no longer useful" or that have "low priority" in an emergency. In other words, plants have mechanisms to turn on the expression of genes that are appropriate for the purpose and to turn off the expression of genes that are not appropriate for the purpose. In this context, I am focusing on the degradation mechanism of specific gene mRNA (Figures 2 and 3) to suppress protein translation from specific gene mRNA.

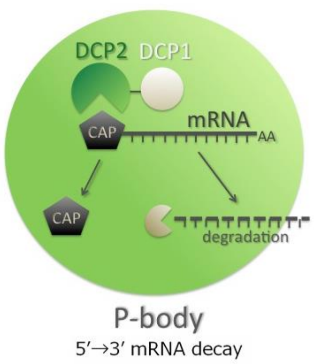

Figure 2 P-body which degrades specific mRNAs. The structure is commonly found in the cytoplasm of eukaryotic organisms; its function is essential for growth and survival.

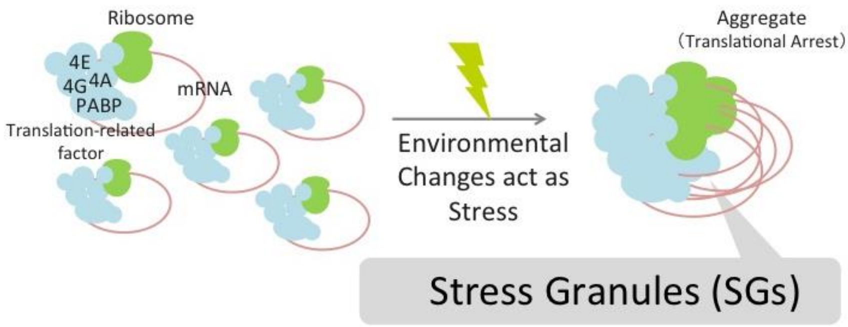

Figure 3 Stress granule (SG) which suppresses the translation from specific mRNAs. The structure is commonly found in the cytoplasm of eukaryotes, and their function is essential for growth by providing emergency refuge for specific mRNAs so that the mRNAs become available again when the crisis passes.

I also have been investigating the mechanism of repression of specific mRNAs by microRNAs, which are non-coding RNAs as short as 19-24 nucleotides in length. To understand the system, I started my research with *Arabidopsis thaliana* (Fig. 4).

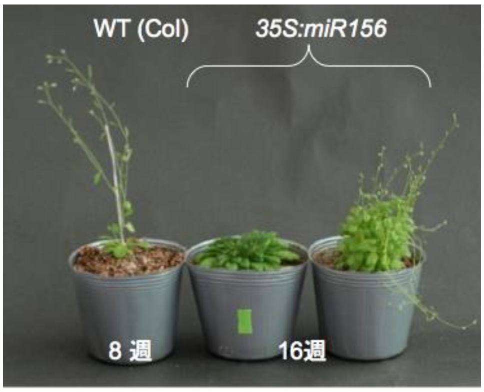

Figure 4 Arabidopsis (*35S:miR156*), which constantly expresses a microRNA called miR156, does not flower easily compared to that wild-type (WT).

And now, I have expanded the study to include liverwort (*Marchantia polymorpha*), phylogenetically located at the base of land plants. Various studies have shown that land plants all have, without exception, standby genes for responding to environmental changes, protein genes involved in the regulatory mechanism of expression, or crisis management mechanisms, as introduced here. I am trying to understand the regulatory expression system related to such crisis management. Through this research, I would like to clarify the essential strategies of the terrestrial plants and build up various ways to make coexistence of human beings and botanical world.