Plants feel the heat

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It's not just humans and animals that suffer when the mercury rises, plants feel the heat too. Heat stress is a major issue in agriculture and can significantly reduce crop yield. Even small increases in temperature can affect plant growth and development. While plants cannot move to a shady spot to escape the heat, they have developed strategies to protect themselves from heat stress when the sun comes out; however, how plants sense and respond to heat stress is not fully understood.

Understanding how plants respond to heat stress is crucial for developing crops that can withstand rising average temperatures and more frequent heat waves under climate change. As a result, many people have been working for many years to try to understand how plants sense temperature and then how plants use this information to activate chemical pathways to protect themselves by, amongst other things, manufacturing protective heat shock proteins (HSP).

It has been known since 1939 (Laude et al) that plants' response to heat stress fluctuates between day and night - if you apply heat stress to a plant during the middle of the day, it is much more likely to survive than if you applied the same heat stress at night. Plants' daily cycle of heat resistance is a strategy that protects plants from the hottest parts of the day, while also potentially preventing energy being wasted producing heat shock proteins at night when it is cooler.

Further studies have confirmed that heat resistance is triggered in plants when they are exposed to light. They lose this heat resistance property in darkness and will only regain the protection when exposed to light again.

However, the signalling involved in telling the plant when to activate genes to manufacture heat shock proteins remained a mystery.

Patrick Dickinson, who joined the Sainsbury Laboratory at the University of Cambridge as a PhD student, wanted to find out: "I was quite interested in how plants respond to their environment and was surprised that there was so much to be learned about how plants sense and respond to temperature. There is a lot known about how plant and animal cells respond to extreme heat stress, but not much was known about their response to ambient heat or how they regulate their response to heat between day and night."

Light-induced chloroplast signalling triggers heat stress response

Dr Dickinson, who is now a Research Associate at the University of Cambridge's Department of Plant Sciences, discovered that a number of genes known to be involved in chloroplast formation were also having a big effect on the plant's response to high temperatures. Putting these two pieces of the jigsaw together - his discovery that chloroplast genes were linked to the heat stress response and that plants respond better to heat stress during daylight - pointed to the chloroplast being involved in protecting the plant from heat. He discovered that there is a signal sent from the chloroplast in response to light, which then activates gene expression in the nucleus to make the plant resistant to heat stress.

How do the chloroplast and nucleus talk to each other?

Following on from this discovery, the next fundamental question to answer is, how is this signal being transmitted from the chloroplast to the nucleus to change gene expression within the cell? Dr Dickinson says the signalling molecule that is transmitting signals from the chloroplast to nucleus is related to the photosynthetic electron transport chain: "There is some sort of signal coming initially from the photosynthetic electron transport chain, which is communicated to the nucleus to activate the gene expression, but what that signal is is not clear yet. It could possibly be hydrogen peroxide because that has been shown to move from the chloroplast to the nucleus to initiate signalling, but there is still a lot more that needs to be looked at to confirm the nature of the signalling."

Practical application

Dr Dickinson's supervisor at Sainsbury Laboratory, Dr Phil Wigge, says it is vital that genes and genetic backgrounds that confer increased resilience to heat stress are identified: "Many of the crops being grown around the world today are already being grown at the top of their comfort zone in terms of temperature. There is actually an estimate that for major crops like wheat, rice and maize, that every degree Celsius rise in temperature above current temperatures could potentially decrease crop yields by between 3-7% due to thermal stress. The contribution that we are trying to make in the lab is to understand the molecules and the underlying mechanisms that control how a plant senses temperature and the genes that are required for a plant to adapt to higher temperatures. And we hope that we can then use that information to discover the same genes in crop plants and see if those genes can be used to make crop plants more resilient to heat stress."

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