B·DEBATE International Center for Scientific Debate BARCELONA

biocat | Obra Social "la Caixa"

Synopsis

WHEN DEVELOPMENT MEETS STRESS:

UNDERSTANDING DEVELOPMENTAL REPROGRAMMING UPON PATHOGENESIS

September, 2018

www.bdebate.org

CO-ORGANIZED BY:

crag · EXCELENCIA SEVERO OCHOA 2016 - 2019

WITH THE SUPPORT OF:

New Phytologist Trust | Photon Systems Instruments | The Company of Biologists

WHEN DEVELOPMENT MEETS STRESS:

UNDERSTANDING DEVELOPMENTAL REPROGRAMMING UPON PATHOGENESIS IN PLANTS

On 3 and 4 September 2018, scientists from around the world met for a session of B·Debate (an initiative of Biocat and the "la Caixa" Foundation to promote scientific debate) to lay the groundwork for a new discipline: personalized agriculture. This new field has two facets: on one hand, studying plant development (how they grow and how this growth can be controlled) and, on the other, how plants defend themselves against pests.

This advance has come about as a result of techniques like mass DNA sequencing, which are responsible for the technological revolution we are experiencing now, becoming more affordable.

So, it is now possible to predict which diseases will affect plants each year (and how they will defend themselves), to suggest which plant variety (of rice, for example) could be more resistant the following year.

The goal is to get greater yield from less land, using fewer chemical treatments and pesticides, with clear benefits for the environment: as this lowers the impact on the environment, it curbs the loss of biodiversity while feeding a larger population. Other plants that could benefit from these advances are tomatoes, corn, lettuce and wheat.

The debate, entitled When development meets stress: Understanding developmental reprogramming upon pathogenesis in plants', was organized in conjunction with the Center for Research in Agricultural Genomics (CRAG).

CONCLUSIONS

- Personalized agriculture is a new discipline that studies both **how plants grow and develop and how they defend themselves against pests**
- Research in this field promises to develop new, **more effective fungicides that are longer-lasting and more eco-friendly**. Another advantage is that more food could be obtained from less land
- Research is currently focused on plants like **rice**, **tomatoes, corn, lettuce and wheat**
- Advances in genomic studies, on top of the techniques used becoming more affordable, are promoting this area of science

1. PERCEIVING PATHOGENS, A KEY AREA

This tug-of-war between the pathogens adapting to the plants' defenses and the plants adapting to their attacks has come about naturally throughout evolution.

Now, understanding these changes will make it possible to find new plant varieties that can carry out this molecular process against pathogens more effectively, as explained Youssef Belkhadir, researcher and group leader at the Gregor Mendel Institute in Vienna.

"One of the challenges is understanding the complexity inherent in root growth. Plus, roots have different ways of integrating and responding to cell damage, to perceiving molecular patterns associated with microbes and other types of stress," noted Niko Geldner, professor at the University of Lausanne (Switzerland).

His research, using laser ablation of single cells, has shed light on how root damage, even when limited, has different implications that damage to leaves.

The studies also focus on prevention: there could be 'dormant' pathogens present in nature that reappear due to a change in precipitation. Another approach is to make plants more resistant to these pathogens.

Climate change is another worry and a great effort is being made to study the relationship between what is regulated by plant defenses and what is regulated by the environment. This is because plant growth (and that of pathogens, too) is determined by environmental temperatures: the warmer the environment, the more pathogens grow and plants have to deal with this additional stress, at higher temperatures and with less water.

One of the numerous areas of research in this field focuses on kinase receptors, a type of enzyme with hundreds of varieties that are encoded in the genome of plants. These enzymes are found on the cell surface and as the professor in the University of Zürich Department of Plant and Microbial Biology Cyril Zipfel stressed, “They control nearly every aspect of plant life, playing a central role: from reproduction to growth and response to the environment.”

Insects can also play a significant role, as they spread pathogens from one plant to another (known by the generic term phytoplasmas), causing significant changes to the architecture of the colonized plant, such as alterations to flower development or growing leaves that are like flowers, and modulating its defense mechanisms.

Pathogens can also have serious economic repercussions. One example is the witch-broom disease epidemic, spread by cicadas, which recently destroyed more than half of the lime trees in Oman and Iran, as well as infecting other citrus trees, like several types of lemons.

“One of the most spectacular biological phenomena is how these parasites can completely hijack a plant, so the host plant becomes a sort of ‘zombie’ focused on ensuring the survival of the parasites above its own survival,” described Saskia Hogenhout, project leader at the John Innes Center in Norwich, United Kingdom. Recently, a multi-layer bioclimatic model was published to help understand the epidemic patterns of these pathogens.[1]

Another disease, called fire blight, affected plants in Switzerland in the past decade. However, in this case, the cause was climate change: higher precipitation levels and warmer springs, noted Sheng Yang He, professor at the MSU-DOE Plant Research Laboratory in East Lansing (United States).

Also, the four serious epidemics of fusarium wilt in wheat that China has suffered over the past five years were caused by the same circumstance, in this case greater precipitation and warmer summers. “The impact of higher temperatures affects both the defenses of the host plant and the virulence of the bacteria.[2] And the impact on growth can be seen both as a result of long-term and short-term temperature rises, for example with heat waves,” the expert explained.

From his point of view, the studies being done on interactions between plants and pathogens should start to look more at the multidimensional nature of the interactions of the disease, the environment and the microbiome in order to better reflect what is happening both to crops and in natural ecosystems.

Possibly the most well-known case, however, is the pathogen *Phytophtfora infestans*, which in the mid-19th century destroyed all of the potato plantations in Ireland, causing a huge famine and enormous economic losses, in addition to the one million people who died of starvation and the other million forced to emigrate. Tolga Bozkurt, a researcher at Imperial College London, focuses his research on this pathogen and points to the key role of a process called selective autophagy combined with defenses to help build immunity.

Advances in high-performance molecular techniques, in addition to the analysis of computational data, have made it possible to better understand the impact plant hormones like cytotoxins and salicylic acid have on activating defenses and their consequences in terms of plant growth, as explained Cris Argueso, professor at Colorado State University (USA).

Another type of approach, known as meta-analysis of gene profiling for the whole genome, carried out by Teva Vernoux at the RDP Laboratory in Lyon (France), has made it possible to describe a network of genes that are kicked off by a small signaling molecule involved in flowering and the growth pattern of plants.

2. CELLULAR BASES OF INTERACTION BETWEEN GROWTH AND DEFENSE

One of the main consequences of pathogen infection is that it disturbs the metabolism of the host plant, including protein synthesis. The work of Xinnian Dong, professor of Biology at Duke University (USA), has shown that plants have a circadian clock that directly controls defense signaling and the expression of genes that anticipate pathogen infection at the time of day when the risk of infection is highest.

“Under immune induction, the circadian clock programs the immune response to avoid conflicting with other physiological processes like transporting water at night. Plus, precipitation changes regulate the plant’s circadian clock to influence various physiological processes like effector-triggered immunity,” she explained.

One important aspect of plants is that they seem to have DNA-repair pathways that are much more efficient than those found in mammals, as highlighted Arp Schnittger, professor at the University of Hamburg.

In this regard, retinoblastoma plays an essential role. This multi-function regulator participates in cell proliferation, development decisions, response to stress and maintaining the integrity of the genome. This is why it is currently the focus of study, as it could provide keys to identifying other ways plants regulate DNA damage.

The cell wall is another structure being analyzed, as explained Clara Sánchez-Rodríguez, assistant professor at the ETH Institute in Zürich. This is because, in addition to providing the plant with stability and protection, it is the first layer that perceives stimuli. For this reason, controlled changes to the structure are essential to the plant adapting its growth to the stresses from its environment.

3. CO-EVOLUTION AND ADAPTATION OF PATHOGENS AND GROWTH AND DEFENSE OF HOST PLANTS

According to Detlef Weigel, director of the Max Planck Institute for Developmental Biology (Tübingen, Germany), the goal over the coming years will be to understand genomic and geographic patterns in the diversity of immune response.

"We've observed that natural variation reveals new aspects of the plant immune system and that, in wild plants, the pathosystems (subsystem defined by the parasite) differ from those of crop and laboratory plants. Also, the tug-of-war between pathogen and host differs if we look at the greenhouse or a field," he stressed.

The project he has just kicked off will be sequencing the whole genome to describe the genetic diversity of the host plant and two significant pathogens: Pseudomonas and Hyaloperonospora arabidopsidis. The goal is to create an allele map of the host plant resistance and another of the pathogen effectors to show whether local adaptation is more common in the plants or the pathogens.

Another of the numerous work lines open was described by Hailing Jin, professor at the University of California, Riverside (USA): small RNA is a type of short, non-coding RNA involved in silencing the genes of another sequence. “We’ve proven that some small RNA in pathogens can be transferred to the host-plant cells, suppressing the immune system so the infection can successfully take hold. One of these fungal pathogens is Botrytis cinerea, which causes what is known as gray mold in more than one thousand plant species. Plus, we’ve shown that this pathogen may have double chains of RNA and small RNA in its environment. And, applying small RNA to the botrytis genes on the surface of fruits, vegetables or flowers inhibits grey mold,”[3] she highlighted. And, in her opinion, this finding opens the door to a new generation of fungicides that are longer-lasting and more eco-friendly.

“For personalized agriculture to become a reality, it is essential for societies to demand that their governments invest more in basic science, which can later be applied. The only limits are those stemming from the funds available to scientists,” explained Ignacio Rubio-Somoza of the University of Barcelona Center for Research in Agricultural Genomics (CRAG) and co-organizer of the event.

Another aspect that must be promoted, in his opinion, is raising general awareness of the fact that scientists “love the earth, nature and the environment more than anyone. And our sole passion is to understand and come up with long-term solutions that are as innocuous as possible. We need to explain ourselves, but the people also have to listen and have the critical thinking and interest in why scientists do what we do. Science education, especially in biology, is key and will stop there from being people who think tomatoes don’t have genes.”

References

1 Tomkins et al, 2018. Curr Opin Plant Biol.

2 Huot et al, 2017. Nature Comm

3 Wang et al, 2016, Nature Plants