



Press Release

Pathogen hijacks fruit ripening program in citrus plants

University of Tübingen-led international research team discovers how a bacterium obtains additional nutrients for reproduction at the expense of the plant

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The bacterial pathogen *Xanthomonas citri*, which causes canker disease in citrus trees, activates selected parts of the fruit ripening program inside infected leaves. Normally, this program makes citrus fruits soften and sweeten as sugars are released. But the bacterium hijacks this fruit-specific machinery in infected leaf tissue, causing the host to unlock sugars that otherwise would not be accessible to *Xanthomonas* as a source of nutrients. As a result, the pathogen can grow up to a hundred times faster. The sophisticated strategy used by *Xanthomonas* bacteria to infect citrus plants was discovered by an international research team led by Professor Thomas Lahaye at the University of Tübingen's Center for Plant Molecular Biology. This study provides new insights into how microbial pathogens hijack the host plant's developmental programs to access otherwise inaccessible nutrients. These findings open up new approaches to combating citrus canker; they have now been published in the journal *Science*.

In the cultivation of citrus fruits such as lemons, oranges, and mandarins, citrus canker is one of the most economically significant plant diseases. Infection with *Xanthomonas citri* causes brown spots and fluid-filled pustules to appear on the affected leaves and fruits of citrus plants, resembling small ulcers – hence the name citrus canker. The plants lose the infected leaves and fruit prematurely, resulting in significant yield losses. “It was known that many pathogens – including *Xanthomonas* bacteria – target the sugars bound up in the plant cell wall,” explains Dr. Trang Phan from the Center for Plant Molecular Biology at the University of Tübingen, the first author of the study. “We were interested in the tricks these tiny bacteria use to extract nutrients from the plant's cell walls, because these walls represent an almost insurmountable protective barrier for many pathogens.”

A small investment with big results

“The bacterium *Xanthomonas citri* uses a syringe-like protein complex to inject various effector proteins into plant cells. These bacterial proteins specifically manipulate cellular processes in host cells to promote infection,” says Thomas Lahaye. “We investigated a particularly important effector protein that travels along the host’s internal transport highways to enter the cell nucleus – the control center of the host cell – in order to understand how it promotes infection there.” Once inside the nucleus, the bacterial effector activates the production of a plant regulator that switches on a ripening program whose components are normally produced only in fruits. “Because the bacterium forces the host to run this fruit-specific ripening program in leaves, cell wall-bound sugars are released directly into the area where the bacteria grow – a clear nutritional advantage that accelerates bacterial growth,” says Lahaye.

Trang Phan and co-author Dr. Jan Grau from the Institute of Computer Science at the University of Halle-Wittenberg jointly evaluated the extensive project data, especially the sequencing datasets, using bioinformatics. A comparison of the genes activated in infected citrus leaves (native program) and in ripening fruit (hijacked program) revealed striking similarities between the two gene sets. These parallels showed that the program triggered by the bacterium in leaves essentially mimics the natural fruit-ripening program. Building on this insight, the team showed that the citrus control protein – and its tomato counterpart – activate similarly structured ripening programs in both tomato and citrus fruits. “By producing effector proteins that reprogram the host’s developmental processes to their advantage, the bacteria are able to utilize large amounts of cell wall-bound sugars with little effort,” explains Trang Phan.

Practical tips for growing citrus

These detailed insights into both the course of infection of citrus plants by *Xanthomonas citri* and the regulation of fruit ripening provide the research team with new leads for developing pest-resistant plants. “While our research aimed to clarify how the pathogen manipulates the host, we also gained new insights into how plants orchestrate fruit ripening. This knowledge could now serve as a basis for using standard genetic modification methods to fine-tune the ripening process. In the future, our findings could help to adjust both the firmness and sweetness of tomatoes and citrus fruits,” says Lahaye.

“Basic research consistently provides concrete insights for applications that can solve global challenges. Our researchers make important contributions to this,” says Professor Karla Pollmann, President of the University of Tübingen.



The dark spots on the leaves and fruit of the lemon tree are typical symptoms of citrus canker, which is caused by infection with *Xanthomonas citri* bacteria.

Photos: Jeffrey B. Jones

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Trang Thi-Thu Phan, Rodrigo Silva Araujo Streit, Gerald V. Minsavage, Joachim Kilian, Paloma de los Angeles Aguilera, Nan Wang, Nicolas Brich, Robert Morbitzer, Edda von Roepenack-Lahaye, Brice Charleux, Boris Szurek, Priscila Oliveira de Giuseppe, Concetta Licciardello, Jeffrey B. Jones, Paulo J. P. L. Teixeira, Gabriela Felix Persinoti, Mario Tyago Murakami, Chang Liu, Jan Grau, Thomas Lahaye: *Xanthomonas* coordinates type III–type II effector synergy by activating fruit ripening pathway. *Science*, <https://doi.org/10.1126/science.adz9239>

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