

Lipopolysaccharide, a potential inducer of plant defense response

Many biotic and abiotic agents increase the potency of the induction of plant defense responses rather than inducing them directly. Lipopolysaccharide (LPS) is a ubiquitous component of Gram-negative bacteria that can induce defense-related responses in plants. LPS can induce the suppression of the hypersensitivity response (HR) but we have a poor understanding of the molecular effects of LPS. Mari-Anne Newman and colleagues [1] now provide evidence of a wider role for LPS in plant–bacterial interactions, beyond its limited activity as a direct inducer of plant defense.

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To investigate the effects of pre-treatment with LPS on bacterial growth, Newman *et al.* inoculated the leaves of pepper (*Capsicum annuum*) with different strains of the phytopathogenic bacteria from the genus *Xanthomonas*. Bacterial growth of *Xanthomonas axonopodis* pv. *vesicatoria* and *Xanthomonas campestris* pv. *campestris* was restricted *in planta*. The authors also found that accumulation of phenolic conjugates, coumaroyl-tyramine (CT) and feruloyl-tyramine (FT), was associated with incompatible

plant–bacteria interactions. Pre-treatment of pepper leaves with LPS caused the two compounds to accumulate much more rapidly than in untreated leaves. They concluded that LPS activates two of the biosynthetic steps involved in FT and CT.

To investigate the mechanisms by which LPS pre-treatment accelerates FT and CT synthesis, Newman *et al.* showed that LPS from both *X. campestris* pv. *campestris* and *Salmonella minnesota* induced accumulation of tyramine hydroxycinnamoyl transferase (THT; an enzyme that catalyzes the synthesis of FT and CT), but not PAL transcripts (an enzyme that catalyzes the CoA derivatives via the phenylpropanoid pathway). Based on these results, they concluded that LPS appears to have two effects that could impinge on the timing of FT and CT synthesis: (1) directly inducing THT and tyrosine decarboxylase (TyDC) and (2) increasing the potency of the induction of TyDC when inoculated with bacteria. Importantly, in addition to working as free compounds, FT and CT will play a role in pathogen resistance when incorporated into the cell wall.

In addition to genes associated with CT and FT metabolism, Newman *et al.* also examined the expression of the genes encoding the pathogenesis-related (PR) proteins PR6, basic β-1, 3-glucanase and

acidic β-1, 3-glucanase using cDNA probes from tomato. They showed that inoculation of pepper leaves with *X. campestris* pv. *campestris* caused induction of genes encoding P6 and basic β-1, 3-glucanase, but acidic β-1, 3-glucanase was not induced. This implies that the effects of LPS on the accelerated accumulation of FT and CT, and on HR suppression, are distinct.

LPS might be involved in the induction of plant defense-related genes by an accelerated synthesis of two antibacterial hydroxycinnamoyl-tyramine conjugates, FT and CT, and enhanced PR gene induction. The effects of increased LPS potency on the synthesis of FT and CT and the effects of LPS on the prevention of HR are both induced in a highly localized fashion within hours of LPS application. If we can use their coordinated induction, it will be advantageous for plant resistance. The main challenge faced by biologists to dissect these diverse effects and to exploit new ways of promoting the ability of plants to resist bacterial diseases.

- 1 Newman, M-A. *et al.* (2002) Prior exposure to lipopolysaccharide potentiates expression of defenses in response to bacteria. *Plant J.* 29, 487–495

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Tailor-made toxin target

The phytopathogenic fungus *Alternaria alternata* has a wide host range. However, certain pathotypes are selectively virulent and cause brown spots on leaves and fruits of specific species or cultivars of *Citrus*, whereas they are relatively harmless to others owing to the production of host-specific toxins. The so-called ACR toxin of the rough lemon pathotype (RLP) causes citrus brown spot disease exclusively on rough lemon. Physiological and ultrastructural data had previously suggested that mitochondria were the site of action of the ACR toxin. Kouhei Ohtani and colleagues [1] have now provided a surprising explanation for the selectivity: the RNA of a mitochondrial gene (*ACRS* for ACR-toxin sensitivity) is

specifically processed to yield a susceptible interaction with the ACR toxin.

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The *ACRS* gene was isolated with an elegant functional assay in ACR-resistant *E. coli*: random expression cloning of rough lemon mitochondrial DNA from the susceptible rough lemon resulted in the identification of a sequence that conferred sensitivity to the toxin. Surprisingly, the responsible gene is located in the intron region of a transfer RNA gene. Even more surprisingly, it is not the mere presence or

absence of the *ACRS* gene that determines the sensitivity or resistance of different citrus cultivars to the ACR-producing fungus, but rather a post-transcriptional modification of the *ACRS* RNA. The *ACRS* gene has identical sequences in all *Citrus* species analyzed, but different transcript size in the susceptible rough lemon compared to other, resistant species. Protein corresponding to the sensitivity-specific transcript could be detected only in mitochondria of rough lemon and seems to be present as a partially sodium dodecyl sulfate-insoluble oligomer *in vivo*. This suggests that *ACRS* might function as part of a transmembrane pore complex – a common target for fungal and bacterial toxins.

Although DNA rearrangements have been previously identified as a basis for different mitochondrial protein equipment, differential RNA processing is a new concept to explain different toxin sensitivity. This sets the stage to investigate the mechanistic mode of action of ACR. Further, it will be of interest to describe the precise function

of the ACRS variants in infected and uninfected tissues, as well as to find out what other function the ACRS RNAs and proteins might have in susceptible and resistant species, in addition to opening or closing a gate to an enemy. Another exciting chapter in the book of combat between plants and microorganisms is opened.

1 Ohtani, K. et al. (2002) Sensitivity to *Alternaria alternata* toxin in citrus because of altered mitochondrial RNA processing. *Proc. Natl. Acad. Sci. U. S. A.* 99, 2439–2444

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In Brief

Trials of pine DNA



DNA evidence from a Norwegian pine forest presented in a recent murder trial might help determine who is the real criminal. In 1999, three people were shot dead at a farmhouse surrounded by the pine trees in Lillestroem, just north of Oslo, Norway. One of the convicted killers, Kristin Kirkemo Haukeland, had suspicious pine needles lodged in her socks. Scientists DNA fingerprinted the needles and found that the needles did not originate from most of the trees around the farmhouse (36 out of 42 possible trees). Leif Sundheim, research director at the Norwegian Crop Research Institute told reporters 'Courts use DNA from human hair, blood or sperm quite extensively. We're using the same techniques with plants.' The police suspect that the killers put socks over their shoes to hide footprints. [Reuters (2002) *Toronto Star* 13 March, p. NE24] TS

VIAGRA helps plants' turgor

VIAGRA® (Pfizer, New York, NY, USA), the name-brand drug for male sexual turgor, has now been shown to be important for plant turgor as well. VIAGRA® gives the body an extra dose of nitric oxide, which dilates blood vessels. Researchers Carlos Garcia-Mata and Lorenzo Lamattina [*Plant Physiol.* (2002) 128, 790–792] and Steven Neill and colleagues [*Plant Physiol.* (2002) 128, 13–16] have made a new connection between nitric oxide and

abscisic acid. Previously, scientists knew that abscisic acid becomes activated in plants under drought stress. The researchers found that abscisic acid works by encouraging cells around the stomata to produce nitric oxide. This increase in nitric oxide signals the stomata to close, which allows the plant to retain water and turgor. It is hoped that this insight into the role of NO in stomatal biology might lead to new ways of manipulating plant's water requirements, possibly improving crop productivity. TS, NC

New spin on crop protection

Michael Hoffman and colleagues (Cornell University, New York, NY, USA) are examining ethylene vinyl acetate (EVA) as an alternative to pesticides to control plant pests. EVA is applied as a 'nonwoven multidimensional fiber barrier' (which looks like 'cotton candy') to crop species such as onions and broccoli. EVA provides a physical barrier that prevents insect pests getting to the plants to lay their eggs that would otherwise develop into maggots that can ravage such crop plants. Although only at an experimental stage, it is seen as an environmentally friendlier alternative to insecticides. [<http://www.news.cornell.edu/releases/Feb02/Hoffmann-IPM.bpf.html>] NC

Tropical ozone control?

Oxygen might not be the only globally affecting gas produced by plants. Methyl chloride gases are well known for their ozone-depleting properties. Methyl chlorides can be made from industry and also naturally from plants. However, there was an unknown source contributing to atmospheric methyl chloride. Now Yoko Yokouchi and colleagues report that a significant emission of methyl chloride comes from tropical plants [*Nature* (2002) 416, 163–165]. From their measurements in

controlled glasshouse conditions in Tsukuba Botanical Gardens (Japan), and in subtropical forests, they have evidence that tropical plants produce a large amount of methyl chloride. Specifically, particular fern families and members of Dipterocarpaceae seemed to be the worst culprits. TS

Have pathogen, will recombine

When plants encounter pathogens, the plants do not play the victim, but instead unleash a variety of responses to ward off the offending bug. Unexpectedly, plants respond to pathogen attack by recombining their DNA in vegetative tissues [*Nat. Genet.* (2002) 30, 311–314]. Jan M. Lucht and colleagues used a clever transgenic system in *Arabidopsis* where recombination events show up as blue-staining cells. When the researchers sprayed plants with fungus, the amount of recombination significantly increased. The same result was also found when the group sprayed on salicylic acid-like chemicals that are sufficient to cause certain defense responses. Lastly, the experimenters used a mutant deficient in plant defense and found that it showed decreased recombination. The recombination might be a general way of dealing with stress by generating variation. TS

Oldest germinating seed

An international team of scientists germinated lotus seeds nearly 500 years old [*Am. J. Bot.* (2002) 89, 236–247]. The team headed by Jane Shen-Miller searched for ancient lotus seeds in the northeastern Chinese village of Xipaozi. All four seeds that they tested for viability germinated and were between 200 and 500 years old. However, the resultant plants all showed abnormalities in their leaves, stalks and underground stems. The researchers