A new blueprint for plant pathogen resistance

A signaling cascade downstream of a leucine-rich repeat receptor kinase identified in Arabidopsis offers new options for engineering crop disease resistance.

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Every year, a large fraction of worldwide crop production falls prey to viral, bacterial, or fungal infection. Such infections not only cause severe losses in world food production, but also can damage human health by contaminating crops with potent carcinogens and toxins. Traditionally, farmers have controlled crop disease through the application of fungicides and pesticides, but these chemicals pose environmental and health problems in themselves if used indiscriminately. Genetic modification allows disease-resistance traits to be introduced into crop plants, usually by overexpression of antimicrobial proteins (e.g., chitinase) or by induction of key plant defense pathways through signaling molecules (e.g., salicylic acid, jasmonic acid, or ethylene). A paper published recently in Nature by Sheen and colleagues describes an additional signaling pathway, the flagellin mitogen-activated protein kinase (MAPK) cascade, that has considerable potential for the engineering of crops with broad-spectrum resistance against fungal and bacterial pathogens.

Plant defense against pathogens is a complex multistep process including the expression of an array of defense genes, the production of a variety of antimicrobial substances, and programmed cell death at the site of attack. In the 1940s, Flor found in genetic experiments that a single dominant plant disease-resistance locus, R, conferred upon flax plants a resistance to infection by rust fungus, and that the fungus' virulence also was dependent on a single fungal gene, Avr (ref. 3). On the basis of these data, generally summarized by the "gene-for-gene" concept of incompatible plant–pathogen interactions, workers set out to identify the underlying mechanisms.

Many R and Avr genes have now been identified. Whereas the Avr genes encode a variety of structurally and functionally different proteins, many plant R proteins share extensive similarity with insect and animal receptors (Fig. 1) that are required for the onset of the innate immune response and are involved in the sensing of pathogen-derived factors, called PAMPs (for pathogen-associated molecular patterns). Although the defense genes in animals and plants differ considerably, signal transduction connecting the activation of the receptors to the induction of the defense responses shows some similarities between kingdoms.

In both animals and plants, kinases of the MAPKs class are activated by PAMPs. MAPK pathways are typically multiprotein complexes containing at minimum a MAPK, a MAPK kinase (MAPKK), and a MAPKK kinase (MAPKKK). MAPKs are ideal intracellular mediators of information, because they shuttle between cytoplasm and nucleus, and among their targets are several classes of transcription factors. Thus, MAPKs represent the mechanistic link between information transfer through the interior of the cell and the transcriptional response in the nucleus.

In their Nature paper, Sheen and colleagues confirm previous studies in various plant systems, including both monocot...