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Hypersensitive Response in Plant

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The hypersensitive response (HR) is a significant feature in many biotrophic plant-microbe interactions, contributing to disease resistance. This phenomenon is marked by the programmed cell death (PCD) of tissues around the area where a pathogen has invaded. The plant HR is a swift localized cell death response that occurs precisely at the site of pathogen entry and is linked to disease resistance. Although others had observed similar occurrences earlier, it's widely attributed that E.C. Stakman was the first to use the term 'hypersensitive'. He described the extraordinary resistance exhibited by specific grass hosts against Puccinia graminis and termed it as 'hypersensitive' due to the plant's response to the fungus (Van Doorn et al., 2011).

HR is a widespread occurrence found in most higher plants and is triggered by various categories of pathogens. The most frequently observed instances of HR are those induced by fungi, oomycetes, bacteria, and viruses. However, HR can also be prompted by other organisms like insects and nematodes, which have sustained close interactions with the host plant. While cell death has been documented in resistant interactions between parasitic plants and their hosts, whether this truly constitutes an HR is uncertain. Understanding the hypersensitive response and its role in disease resistance is crucial for developing effective strategies for managing plant diseases.

HR as a Form of Programmed Cell Death

Programmed cell death (PCD) is often defined as the death of a cell, guided by an intracellular program. By this definition, the hypersensitive response (HR) can be clearly classified as a form of PCD (Birch et al., 2018). Many features of HR align with apoptotic and/or autophagic cell death, two well-characterized types of PCD in animals that are believed to exist in some capacity in plants as well. These shared features encompass phenomena such as cytoplasmic/protoplast collapse, cessation of cytoplasmic streaming, disruption of the cytoskeleton, DNA laddering, formation of large vesicles, and involvement of mitochondria. These shared features have been summarized in various studies, and the general consensus is that while HR shares similarities with apoptosis and other types of PCD, it should be acknowledged as a specialized form of cell death (Van Doorn et al., 2011). It's important to note that HR is not a uniform process and can exhibit variations based on the plantpathogen interactions and the specific context. This underscores the complexity of PCD mechanisms and their role in different biological systems.

Systemic Resistance: Exploiting HR to Engineer Disease-Resistant Plants

The hypersensitive response (HR) often has the ability to induce systemic acquired resistance (SAR), which is a form of enhanced resistance to a wide range of pathogens throughout the entire plant following a localized infection by a necrotizing pathogen or after treatment with certain chemical agents (Menna et al., 2015) SAR is dependent on the phytohormone salicylate (salicylic acid, SA) and is associated with the accumulation of pathogenesis-related (PR) proteins like PR1, PR2, and PR5. The response to elevated SA levels involves proteins NPR1, NPR3, and NPR4, with NPR3 and NPR4 acting as SA receptors and mediating the actions of the transcriptional regulator NPR1, which is considered the key regulator of SAR responses. It has been observed that both mild and extreme leaf flecking are linked to broad-spectrum resistance (Olukolu et al., 2016). While extreme flecking might lead to yield penalties, milder forms do not. This suggests that low-level activation of HR, leading to SAR, might be harnessed to provide disease resistance without causing significant yield losses. One potential strategy could involve using development-specific promoters that initiate gene expression after the flowering stage, a time when many diseases become more prevalent, yet after most of the plant's growth has occurred. This approach seeks to strike a balance between effective disease resistance and maintaining satisfactory yield levels. However, further research is needed to refine and implement such strategies effectively.

Conclusion

The ongoing "arms race" between host organisms and their parasites has played a significant role in shaping the evolution of life on Earth. It's even been proposed that sexual reproduction itself could have evolved as a response to the need for hosts to adapt and counter disease pressure. The hypersensitive response (HR) triggered by NLR proteins is a widespread phenomenon across the plant kingdom and has far-reaching effects on various aspects of plant growth and development beyond just disease resistance. The control of HR activation involves a sophisticated architectural system with multiple layers of regulation. However, inappropriate activation of HR can still occur, leading to negative consequences such as the development of lesion-like symptoms that hinder growth, increased vulnerability to necrotrophic pathogens, instances of hybrid necrosis, and even potential speciation. Interestingly, most plant species carry over 100 NLRs in their genomes, with some having even more (for example, Arabidopsis has more than 100, and tomato has more than 400). This abundance of potentially powerful genes, along with the intricate mechanisms in place to manage their potentially harmful effects, underscores the immense significance of disease resistance, particularly mechanisms like HR, throughout the course of plant evolution. The continuous co-evolutionary interactions between hosts and pathogens have indeed left a lasting impact on the diversity and complexity of life on our planet.

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