



Plant Immune Receptor Signaling: Mechanisms of Pathogen Recognition and Defense Activation

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Introduction

Plants are constantly challenged by a wide range of pathogens, including bacteria, fungi, viruses, and insects. To survive these threats, plants rely on an innate immune system capable of detecting invading organisms and activating effective defense responses. Central to this system are **plant immune receptors**, which perceive pathogen-derived signals and initiate downstream signaling cascades. Plant immune receptor signaling forms the foundation of plant defense and is critical for disease resistance, crop protection, and sustainable agriculture [1,2].

Discussion

Plant immune receptor signaling operates through two interconnected layers: **pattern-triggered immunity (PTI)** and **effector-triggered immunity (ETI)**. PTI is initiated when cell-surface receptors known as pattern recognition receptors (PRRs) detect conserved microbial molecules called pathogen-associated molecular patterns (PAMPs), such as bacterial flagellin or fungal chitin. PRRs, including receptor-like kinases (RLKs) and receptor-like proteins (RLPs), activate signaling pathways that lead to rapid defense responses. These include calcium influx, production of reactive oxygen species (ROS), activation of mitogen-activated protein kinase (MAPK) cascades, and expression of defense-related genes [3,4].

ETI represents a second, more robust layer of immunity mediated

by intracellular immune receptors, primarily **nucleotide-binding leucine-rich repeat (NLR)** proteins. NLRs recognize specific pathogen effector proteins either directly or indirectly by monitoring modifications to host proteins. Upon activation, NLRs trigger strong immune responses, often including localized programmed cell death known as the hypersensitive response, which restricts pathogen spread. Recent research has shown that ETI amplifies and sustains PTI signaling, highlighting the integration between these two immune layers [5].

Plant immune receptor signaling is tightly regulated to balance defense and growth. Hormonal pathways involving salicylic acid, jasmonic acid, and ethylene modulate immune signaling depending on the type of pathogen encountered. Transcription factors such as WRKY and NAC families play key roles in translating receptor activation into appropriate gene expression responses. Additionally, post-translational modifications, protein complexes, and subcellular localization contribute to the fine-tuning of immune signaling.

Advances in molecular biology and genomics have greatly expanded our understanding of immune receptor diversity and function. This knowledge is being applied to crop improvement through breeding, gene pyramiding, and genome editing approaches aimed at enhancing disease resistance without compromising yield.

Conclusion

Plant immune receptor signaling is a sophisticated and dynamic system that enables plants to detect pathogens and activate effective defense responses. Through coordinated action of surface and intracellular receptors, plants mount multilayered immunity while maintaining growth and development. Continued research into immune receptor signaling will support the development of disease-resistant crops, reduce chemical pesticide use, and contribute to sustainable agricultural systems worldwide.

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