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*CORRESPONDENCE
Anjana Rustagi
✉ anjana.rustagi@gurgicollege.ac.in

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The calcium connection: exploring the intricacies of calcium signaling in plant- microbe interactions

Neelam Prabha Negi¹, Geeta Prakash², Parul Narwal¹,
Ruby Panwar², Deepak Kumar², Bharti Chaudhry³
and Anjana Rustagi^{1*}

¹University Institute of Biotechnology, Chandigarh University, Mohali, India, ²Department of Botany, Gargi College, New Delhi, India, ³Department of Botany, Institute of Science, Banaras Hindu University, Varanasi, Uttar Pradesh, India, ⁴Department of Botany, Ramjas College, New Delhi, India

The process of plant immune response is orchestrated by intracellular signaling molecules. Since plants are devoid of a humoral system, they develop extensive mechanism of pathogen recognition, signal perception, and intricate cell signaling for their protection from biotic and abiotic stresses. The pathogenic attack induces calcium ion accumulation in the plant cells, resulting in calcium signatures that regulate the synthesis of proteins of defense system. These calcium signatures induct different calcium dependent proteins such as calmodulins (CaMs), calcineurin B-like proteins (CBLs), calcium-dependent protein kinases (CDPKs) and other signaling molecules to orchestrate the complex defense signaling. Using advanced biotechnological tools, the role of Ca²⁺ signaling during plant-microbe interactions and the role of CaM/CaMLs and CDPKs in plant defense mechanism has been revealed to some extent. The Emerging perspectives on calcium signaling in plant-microbe interactions suggest that this complex interplay could be harnessed to improve plant resistance against pathogenic microbes. We present here an overview of current understanding in calcium signatures during plant-microbe interaction so as to imbibe a future direction of research.

KEYWORDS

Ca²⁺ signaling, plant-microbe interaction, endophytes, biotic stress, omics, CRISPR

Introduction

Calcium ions (Ca²⁺) play an important role in various plant functions, like providing structural support, nutrition, and inducing stress responses. Besides these, Ca²⁺ functions as a secondary messenger in cell to cell signaling, and disruptions in its levels occur during biotic or abiotic stress responses (Ghosh et al., 2022). Under different stress conditions, there are spikes in Ca²⁺ concentration within the cell cytosol, known as “calcium signatures”. These Ca²⁺ spikes can be sensed by different calcium influx and efflux

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