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ROLE OF CA^{2+} IONS IN PLANT DEFENSE ACTIVITY AND SECONDARY SIGNALLING

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Introduction

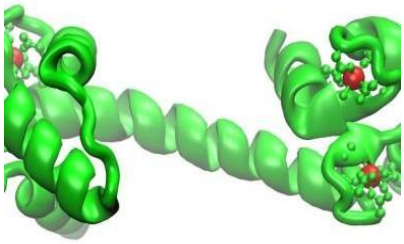
Plants are constantly subjected to various kinds of biotic and the abiotic stresses throughout their life cycle. The biotic stresses including various animate microscopic organisms such as fungi, bacteria, protozoa and several helminths and helminth-ova whereas there also several non-animate agents like stress, drought, cold injury, freezing can also provoke the plants innate immune response to a heightened level. Besides these agents the submicroscopic agents like viruses are also known to induce the plant defense activity to an elevated level through a variety of complex intricate mechanisms.

Now, this article briefly discusses about one of the most prominent ions (Ca^{2+} ions) involved in triggering the plant defense activity and their mechanism in provoking the immune response and their role as a secondary messenger. Let's delve into the world of Ca^{2+} ions and its complex intricate mechanisms in activating the defense related actions.

There are thousands of ions present in the cytosol of the plant cells but very few ions like Mg^{2+} and Ca^{2+} have the prominent roles in activating the defense related proteins and enzymes. Out of these two ions Ca^{2+} have significant role in activating and provoking the plants defense related actions in response to the external stimuli.

Stand-alone features of Ca^{2+} ions:

The Ca^{2+} ions are stored in the Vacuoles, Rough Endoplasmic Reticulum (RER) and Smooth Endoplasmic Reticulum (SER) and in the Mitochondria. The receptors (site of attachment) of many protein-like compounds present in the cytosols of plant cells have their inherent ability to decode (understand) the Ca^{2+} ions producing signals such as **Calmodulins, Calcineurin B and Calcium dependent protein kinases.**



Structure of Calmodulin

Structure of Calcineurin B

These signals are nothing but the Ca^{2+} ions producing signals which are very easily received by many defense proteins inside the plant cells.

Plants response to the pathogens:

When the plants perceive the presence of the fungal plant pathogens through the special receptors. The special type of receptors recognizes the MaMp or apoplastic effectors like proteins.

Incase of bacteria the plant can able to recognize the special components produced by the bacteria such as lipo-polysaccharides, flagellin (a kind of incomplete protein with partial sets of amino acids) and perceive the presence of bacterial plant pathogens. Once the plants perceive the presence of phytopathogens through the special receptors the plants can trigger the cascade signalling (chain like signalling) through the Ca^{2+} ions which leads to activation of defense enzymes and the induction of **phytohormones like ethylene and ABA.**

The ABA and ethylene then attached to **specific receptors (KAT-1)** that pulls down the K^{+} ions from the stomatal guard cells and also the cell wall thickening, induction of HR (Hypersensitive responses a type of programmed cell death to rescue the uninfected cells from the pathogen attack) and the production of PR proteins (Pathogenesis related proteins).

Restoration of Ca^{2+} ions after the immune response:

After the perception of the plant pathogen by plants, then the plant triggers signal transduction pathway (i.e., Ca^{2+} pathway) and it leads to the enormous amount of influx of Ca^{2+} ions into the cytoplasm of the cells from the source **[Vacuoles, Rough Endoplasmic Reticulum (RER) and Smooth Endoplasmic Reticulum (SER) and in the Mitochondria].** The enormous amounts of increase of Ca^{2+} ions in the cytoplasm due to pathogenic perception is called as Calcium Signature. The proteins such as **Ca^{2+} ATPases provide energy for the influx of the calcium ions.** and drag the calcium ions from. mitochondria, vacuoles, endoplasmic reticulum into the cytoplasm of cells.

Removal of Ca^{2+} ions after the immune response:

Too much of anything is good for nothing. Like that way, higher concentration of calcium ion is also **phytotoxic to the plants.** So, the excess of calcium ion after that signal perception by the pathogen should be removed from the cytoplasm. **Some of the proteins such as Ca^{2+}/H^{+} and Ca^{2+} ATPases (Antiporters) Responsible for the calcium ion efflux from the cytoplasm.**

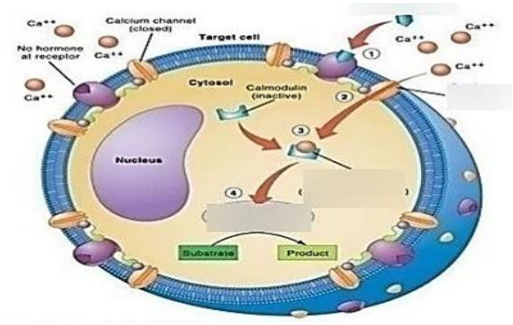
In short, the calcium signaling and the plant defense responses a sequential process

1. Plants initially perceive the signals from the pathogen through the PRR (Pathogen recognition receptors) through the Pathogen Associated Molecular Patterns (PAMP)

2. Now, the pathogen recognizes the pattern and thus leads to transient increase in of the Ca^{2+} ions (To send the effective signaling to induce the resistant mechanism)

3. These calcium ions recognized and then decoded by the calcium binding routines such as Calmodulins, Calcineurin B and Calcium dependent protein kinases (CDPKs)

4. The activated calcium ions (after the pathogen perception) tend to activate the complex downstream processing Includes ROS production, PR Proteins, Fighter hormones induction etc.,



Diagrammatic representation of Calcium-Calmodulin as Secondary messengers

Binding site of Ca^{2+} ions

The calcium ions binding site containing many negatively charged or polar minor acid residues such as aspartate, asparagine, glutamate. Thus, ionic bonds are formed between these binding proteins and the calcium ions.

These are the signature features of the calcium ions in the secondary messenger activity and in activating the plant innate defense mechanism against various kinds of biotic and the abiotic stresses that plants encounter during their life cycle.