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Plant Signaling in Response to Environmental Stresses

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Abstract

Plants responses to these stresses are complex and involve numerous physiological, molecular, and cellular adaptations. Recent evidence shows that a combination of abiotic and biotic stress can have a positive effect on plant performance by reducing the susceptibility to biotic stress. Such an interaction between both types of stress points to an interaction between their respective signalling pathways. Although plant species vary in their sensitivity and responses to the environmental stresses. It may be assumed that all plants have encoded capability for stress perception, signalling and responses. In current review focused on detailed explanation of Effect of various environmental stresses and signalling mechanism of plants as well as responses of plants to them on different development stages has been studied extensively for improvement in understanding the actual mechanism happens inside the plant when they face any stress condition.

Keywords: Abiotic stress, Biotic stress, Cellular responses and signalling, Environmental stresses, Hormones, Tolerance

Introduction

Plant are Subjected to a wide range of environmental stresses, which reduces and limits the productivity of agricultural crops (Verma *et al.*, 2013). A crucial step in plant defence is the timely perception of the stress in order to respond in a rapid and efficient manner (Sah *et al.*, 2016). After recognition lead to an activation of complex signalling cascades of defence varying from one stress to another. Following exposure to abiotic and biotic stress, specific ion channels and kinase cascade are activated reactive oxygen species, phytohormones like abscisic acid, salicylic acid, jasmonic acid and ethylene. Accumulate and a reprogramming of the genetic machinery results in an adequate defence reaction and in plant tolerances in order to minimize the biological damage caused by the stress (Ben *et al.*, 2014). Stress is kind of pressures or strain on the organism which resulting in the physiological changes happens in or on the plants (Csonka, 1989). Stress signalling as central to plants which as immobile organism have to endure environmental fluctuations that constantly interfere with vigorous growth.as results plant specific, elaborate mechanism have evolved to perceive and response to stress condition, Plants have developed various mechanism in order to overcome

these threats of biotic and abiotic stresses. They sense the external stress environment, get stimulated and then generate appropriate cellular responses (Sah *et al.*, 2016). They do this by stimuli received from the sensor located on the cell surface or cytoplasm and transfer to the transcriptional machinery situated in the nucleus, with the help of various transduction pathway (Tuteja *et al.*, 2007) This leads to differential transcriptional changes making the plant tolerant against the stress memory is still being developed each day. In the natural environmental plants are exposed to a variety of biotic and abiotic stress condition that triggered rapid changes in physiological parameters of plants (Ben *et al.*, 2014). In recent years researcher has mainly concentrated on understanding plant responses to individual abiotic and biotic stresses (Bartels and Nelson, 1994). These problems have addressed and are target of research in plant physiology with respect to environmental stresses have opened new challenges for development of new technologies to overcome the problem which are accused by various environmental stress affecting the growth of plants as inability of plants for movement. Two types of environmental stresses are encountered to plants which can be categorised as an Abiotic stress and Biotic stress (Csonka, 1989).

Biotic stress: Biotic stress in plants caused by living organism, especially viruses, herbivores bacteria, fungi, nematodes, insects and weeds (Verma *et al.*, 2013).

Abiotic stress: The abiotic stress imposed on plants by non-living factors such as salinity, temperature, drought, floods and cold (Verma *et al.*, 2013).

Signalling Mechanism of Plants in Response to Environmental Stresses: The first response i.e., cellular response is only initiated when the Extracellular material is interacted with plasma membrane protein. These extracellular molecules are known as an Elicitor/ Ligand and protein which interact or binds to these molecules are known as receptor (Mahajan and Tuteja, 2005).

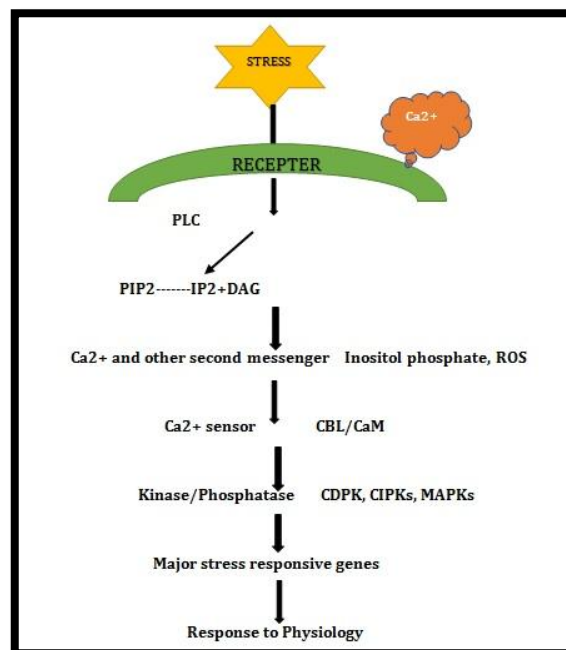


Figure 1: Signaling pathway under stress conditions (Mahajan and Tuteja, 2005)

Signalling Mechanism of Plants in Response to Stress Responsive Genes: Stress Responsive Genes:

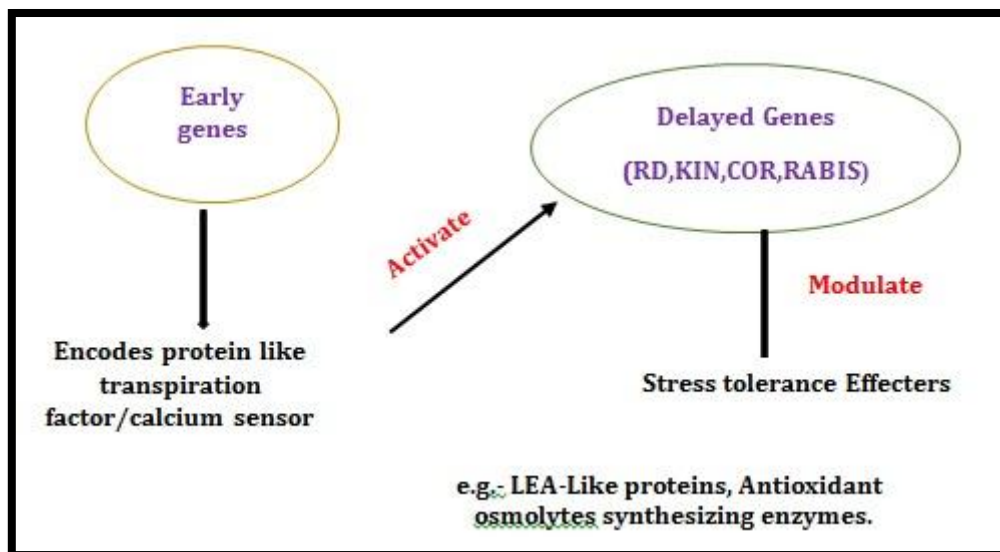


Figure 2: Stress responsive genes (Mahajan and Tuteja, 2005)

The above diagrammatic representation is giving the brief and sample idea about how signalling mechanism is taking place during the stressed condition, expression of genes in response to stress conditions and it represent in stressed condition actual signalling pathway overview (Dubcovsky *et al.*, 1994; Shilpi *et al.*, 2008). On the membrane of plant cell receptors are presents. Which are responsible for the signal perception. After stress is perceived by the receptor it transduced downstream and secondary messenger are generate i.e., Inositol phosphate, calcium reactive oxygen species (ROS).out of which the inositol phosphate is modulate the intracellular level of calcium. This perturbation of calcium level in cytosol is sensed by the sensor called as calcium binding proteins and does not show any enzymatic activity but in calcium dependant manner their conformation is change, later on the interaction of sensor proteins and their respective partner is taking place then it results in to an initiation of cascade of phosphorylation and stress responsive gene should be targeted or transcription factors are controlling them. The end product formation taking place by these stressed genes and it leads to adaptation of plants and also helps to plants survived in unfavourable conditions (Mahajan and Tuteja, 2005). So, the plants employees the various mechanisms to deal with different environmental conditions.

Plant Signalling and Response to Biotic Stresses and Abiotic Stresses: Different mechanism has been developed through research approaches to overcome environmental stresses i.e., Physiological, Biochemical, molecular and genetic changed.

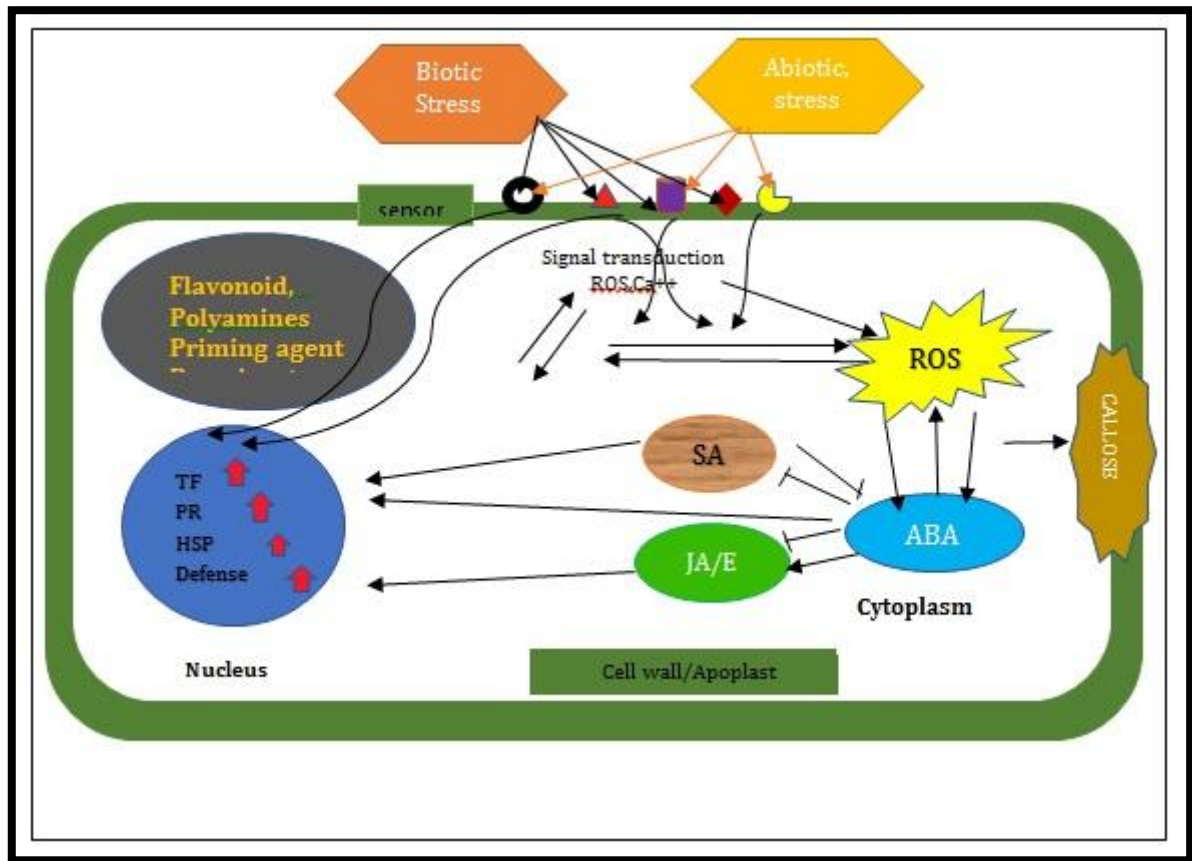


Figure 3: Plant Signaling and Response to Biotic Stresses and Abiotic Stresses

A) Biotic Stress and Signalling Mechanism of Plants Against Them Explained in Details with Example:

The biotic stresses in plants can be overcome by studying the genetic mechanism of the agents causing these stresses. Genetically modified plants have proven to be the great efforts against stresses in plants by developing resistant varieties of crop plants (Alcazar *et al.*, 2006; Verma *et al.*, 2013; Abbas *et al.*, 2013; Iqbal *et al.*, 2021).

We can study plant defence mechanism under two categories i.e., tolerance and defences.

a) Defence: low level damage can be completely compensated by plants in term of fitness.

- Physical defence-example- thorns on rose, spines on a cactus.
- Chemical defence- Are secondary metabolites-carbon based and nitrogen-based defences (Bigeard *et al.*, 2015)
- Some plants can attract natural enemies to herbivores-indirect defence for example ants reduced herbivory

b) Tolerance: photosynthetic enhancement, growth enhancement advancing the timing of bud break. Delaying the senescence of infected tissue, increasing nutrients uptakes (Tuteja and Mahajan, 2007).

B) Abiotic Stress and Signalling Mechanism of Plants Against Them with Example:

Plant first line of defence against abiotic stress in its roots. One of the primary responses to abiotic stress such as high salinity is the disruption of the Na^+/K^+ ratio in the cytoplasm of the plant cell. The Phytohormones abscisic acid (ABA) plays an important role during plant adaptation to environmental stress such as high salinity, drought, low temperature or mechanical wounding (Zhu, 2002).

Tolerance: 1) Reduction in water loss: Reduced transcription by closure of stomata by maintaining ABA synthesis from carotenoid by ABA synthesizing enzyme in root tip enters in to xylem vessel from root to tip leaves regulates metabolism and stomatal behaviour under water stress (Zhu, 2002).

2) Protection of photosynthetic machinery: Wilting of leaves protects photosynthetic machinery from direct sun rays. and stomatal closure (Sah *et al.*, 2016).

3) Osmotic adjustment: Synthesis and accumulates compatible solutes and ions under water stress. Proline and glycine betaine highly compatible solutes increases cellular pressures and protect against water loss in leaves (Zhu, 2002).

Conclusion

The study of stress responses will enhance our knowledge of basic plant Biochemistry. By studying how plants respond to server stresses, we learn more about metabolism, its flexibility, its limits, and its diversity. inability to move and the lack of mobile defender cell add more complexity in defences signalling in plants. The present review provides elaborated information on how plants perceive and respond to multiple environmental stresses. Plant perceives the information signal of each stress and consequently activate specific molecules will participate in the defence response to the specific stress combination and thus contribute to protect the plants and enhance its resistance.

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Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship and publication of this article.

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