

Plant Signal Transduction

Single Transduction Pathways in Plants:

Plant cells, due to their sessile nature, are able to interact with its surrounding environment. Plants use various environmental signals to alter their mode of developmental morphology. Throughout their life cycle, plant and plant cells respond to both internal and external signals, such as nutrients, organic metabolites, water availability, light, temperature, germination, growth and flowering.

Sometimes plants respond to harsh environmental stresses at cellular and molecular level, as well as at physiological levels to confer tolerance of the stress and ensure better survivality.

The genome sequences of Arabidopsis and rice have now been determined and have revealed the presence of complex gene families that encode signalling molecules and transcription factors (TFs). There are as many as 1800 genes that encode transcription factor, more than 600 genes that encode protein kinases and major junk of 600 genes that encode F-box proteins particularly in Arabidopsis genome.

The participation and stability of signalling factors and TFs is indispensable for the regulation of signal pathways. In addition, post transcriptional regulation at RNA level also leads to various other signalling pathways (Fig. 4.1).

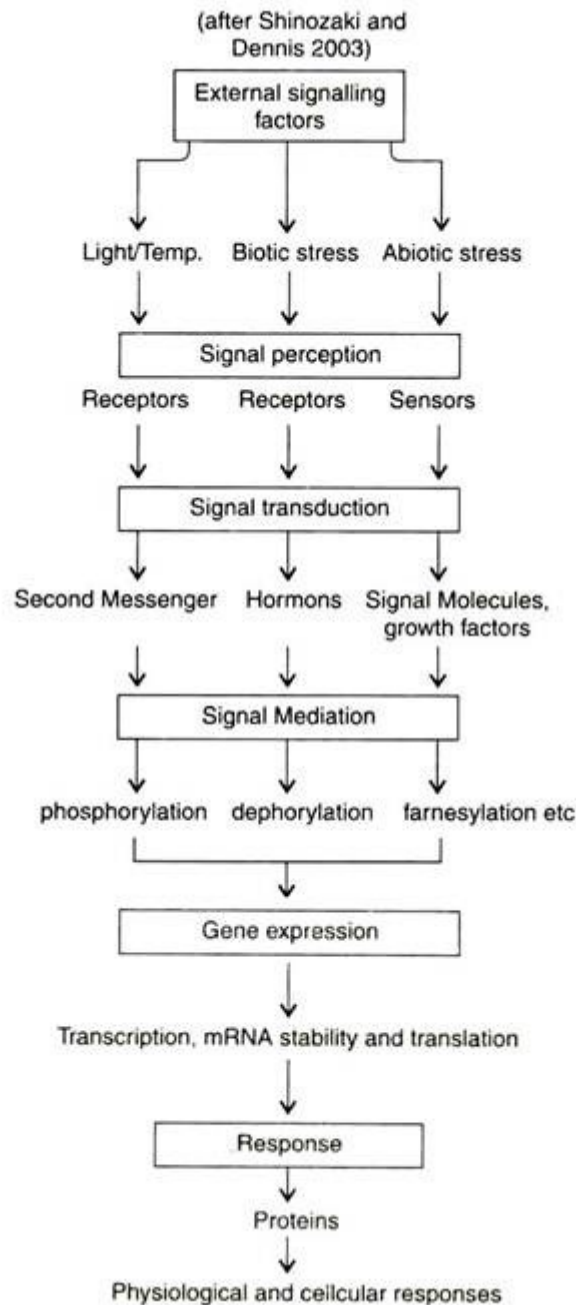


Fig. 4.1 Signal transduction pathways in plants

Mechanism of Signal Transduction:

Generally, signal transduction is initiated by sensing of signal by a receptor. These receptors are either located in the plasma membrane or in the cytoplasm or restricted to cellular compartments. The receptors happen to be a protein. The plasma membrane by virtue of its membrane potential can act as receptor by employing proteinaceous pores, called channels, to control in and out flux of ions through the cell.

As a consequence of alteration in membrane potential opens a group of voltage gated channel that allow Ca^{2+} to enter and initiate transduction sequence. Several signals such as light wavelength (red < blue), fungal elicitors or growth regulators can modify membrane potential. Several unique receptors have been characterized in the cells.

Some transmembrane protein receptors are phosphorylated by protein kinases. In plants, receptor-like protein consists of a large extra cytoplasmic domain with active site of a protein kinase involves in signal transduction process. Binding of ligand leading to dimerization of the receptor and brings protein domains into very close proximity of the cytoplasm.

This receptor complex is then activated by phosphorylation. The active RLK complex interacts with membrane bound or soluble transduction proteins to initiate the signal transduction in a different direction. Several RLKs have been characterised in plant cells including protein kinases which are implicated in incompatibility process and precludes fertilization.

Calcium Signalling in Plants:

The Ca^{2+} ion is being established as a signalling molecule in plants. Several plant signal transduction processes have been shown to employ Ca^{2+} as an integral signalling molecule. In plants, Ca^{2+} ion acts as second messenger, a term often used to describe readily diffusible molecules, conveys information from outside to the largest enzymes within the cell.

The cytosolic level of Ca^{2+} plays a significant role in understanding signalling. Several Ca^{2+} signalling mediated responses have been observed in plants. Many exhaustive reviews on Ca^{2+} signalling in plants have already been published and its elaboration is beyond the scope of this book.

In plants, Ca^{2+} ions in cytosol are maintained at many orders of magnitude lower than in the cell wall. During signalling, elevation of Ca^{2+} level takes place which is associated with initiation of responses. The calcium act on several proteins involved in signalling of which protein kinases is prominent. Among Ca^{2+} mediated signal responses, prominent ones are initiation of Stomatal aperture closure in guard cell, direction of growth in tubes and wall thickening in seedling in response to wind.

In stomatal guard cell, abscisic acid induces elevation in $[Ca^{2+}]$ and cytochromes were found to be unevenly distributed. The Ca^{2+} signalling in plants is in the form of a Ca^{2+} waves. Increase in Ca^{2+} elevation after exposure to hypo-osmotic stress leads to clustering of Ca^{2+} and is thaliana guard cells showed that SIP modules guard cell turgor by affecting the activities of the plasma membrane K^+ channels and slow anion channels.

Sphingosine-1-phosphate mediated changes in guard cell turgor can be transduced via the second messenger Ca^{2+} and through a protein a subunit (GPA1) (Fig. 4.5).

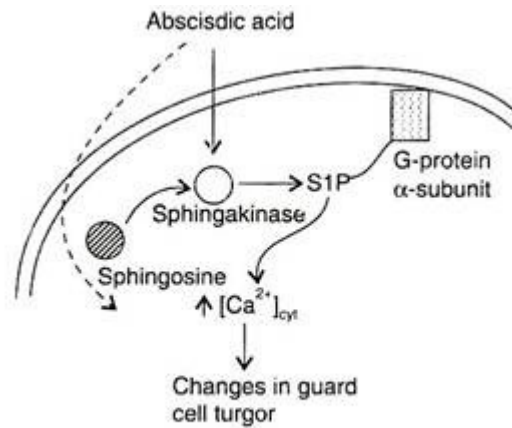


Fig. 4.5 Sphingolipid-mediated signalling in plants

Other Plant Signalling Molecules:

Jasmonate:

Jasmonates are biologically active signalling molecules controlling metabolic, development and defence response in plants. Jasmonic acid (JA) is synthesised at its terminal end product in octadecanoid pathways, and several intermediates in this pathway for JA synthesis, also act as signalling molecule which affect a variety of plant processes including fruit ripening, production of viable pollen, root growth and biotic as well as abiotic stress, particularly in defence response against insect and pathogen attack.

In addition to JA, its precursor 12-oxophytodienoic acid (OPDA) and other oxylipins act as signal molecule for defence suggests that plant response to pathogen attack may be regulated by a complex mix of signals, otherwise termed as oxylipin signature.

The production of JA leads to the induction of many genes such as vegetative storage protein and a plant defence in. It also facilitates transcription of genes that regulate JA synthesis. Microarray analysis confirmed that at least five out of 41 Jasmonate responsive genes are involved in JA biosynthesis.

In tomato plant, systemic induction of JA response occurs through system in signal pathway. Systemin, an 18-aminoacid polypeptide acts as primary signal for the activation of defence genes in leaves of wounded tomato plants. Systemin causes a cascade of intracellular signalling events leading to the release of linolenic acid from plasma membrane. Conversion of linolenic acid into oxylipin signals the expression of defense genes.

14.3.3 Proteins Signalling:

14.3.3 Proteins are phosphoserine binding proteins that regulate the activities of several signal transduction and transcription through direct protein-protein interactions. In plants, one of the best roles of 14.3.3 is in the regulation of enzymes of primary metabolism and other house-keeping functions.

Almost all 14.3.3 protein-protein interactions involved in signalling at some level and affect the activities of various enzymes and ion channels. For example, plasma membrane proton pumping ATPase (H^+ ATPase) and nitrate reductase are activated and inhibited by 14.3.3.

Nitrate reductase is inactivated by 14.3.3 following phosphorylation by protein kinases responding to light-dark transitions. Similarly, 14.3.3 binding site in the H⁺ ATPase of stomatal guard cell undergoes phosphorylation in response to blue light as final step in signalling pathway in order to increase stomatal aperture. In addition, 14.3.3 proteins are also implicated in several signal pathways which involves carbon and nitrogen metabolism.