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Role of MAPK in regulation of ROS under environmental stress

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Abstract
Plants confront many abiotic and biotic factors like diseases, insect, salt, drought, mineral stresses, heat and cold stress throughout their life cycle. As a result plant shows a complex signaling cascade that is mitogen activated protein **(**MAP) Kinase pathway; when it encounters with different environmental stresses it gives a particular response against it. Here MAPK activated by the ROS, which act as a secondary messenger it is when the plant get any environmental stress there is an increase in the Abscisic acid (ABA) that is through phosphorelay mechanism and hence activates ABA pathway. ROS leads to enhance when plant encounter with different environmental stresses and this results in the programmed cell death (PCD) and to avoid such higher production of ROS plants scavenges with antioxidants enzymes and metabolites. Counteract to scavenge toxic ROS and furthermore the plant combat and survive under stressed conditions.

Keywords: ROS, MAPK, environmental stress, ABA pathway

Introduction
Nowadays agricultural sector faces the huge environmental problems and most likely are of Salt, drought, temperature and mineral toxicity. To combat with such situations, the plant undergoes complex signalling cascade transduction mechanism that is the MAP Kinase pathway. So, when the plant gets any environmental stress it get receipted by the cell wall receptors and then it transduce the signal to the nucleus and furthermore activating the genes to encounter with the environmental stimulus. To reveal a meticulous response, it is important for plants recognize the stimulus and convey it with the nucleus of the plant cell [1]. Besides these the organelle like chloroplast and mitochondria are mainly produced by cell wall NADPH oxidases, peroxidases, which are scavenged by scavenging enzymes [2,3]. In this ROS act as a secondary messenger, but when the level of ROS is high, then it undergoes programmed cell death that is eliminating the damaged tissue, but this is regulated by the ROS and through the antioxidative scavengers such as antioxidant enzymes and metabolites. Therefore, protecting the plant from the adverse environmental conditions.

MAP Kinases
MAP Kinase signaling pathway mainly activated during biotic and abiotic stresses are mainly extracellular signal regulated protein kinases. They transduces the extracellular signals sensed by the cell wall receptors of plant cell and lead to cellular responses within the cell. They do so by activating specific serine/threonine MAP Kinase enzyme causing dual Phosphorylation of tyrosine and threonine. MAPK regulates cell functions including proliferation, differentiation, mitosis, gene expression, apoptosis and cell survival [4]. MAPKs are basically part of CMGC (CDK/MAPK/GSK3/CLK) Kinase family and CDKs are its closest relatives [5]. Pharmacological inhibitors like phosphatases and kinases have been used to inhibit PR (pathogenesis related) protein production and HR (hypersensitive response). This showed that protein kinases might have a role in defense. The cloning *Pto* resistance gene supported this.

Mechanism of MAP Kinase signal cascade
Role of MAP Kinases during abiotic stress
As we know MAPKs is highly complex signaling cascade and often it involves the activity of one or more MAP Kinases and there is core three kinase cascade types of MAPKs that is MAP, MAP2K, MAP3K. MAP kinase cascades composed of MAP kinase kinase kinases (MAP3Ks/MAPKKKs/MEKKs), MAP kinase kinases (MAP2Ks/MAPKKs/MEKs/MKKs) and MAP kinases (MAPKs/MPKs) [6]. Now, MAP3K regulates phosphorylation and leads to activation of other mitogen activated protein kinases. MAP2Ks phosphorylate MAPKs on threonine and tyrosine residues at a conserved T-X-Y motif [7]. MAPK is also known as ERK

Pathway (Ras –Raf – MEK –ERK Pathway) and it is highly conserved in eukaryotes and it's also present in prokaryotes, fungi and plants too. By combination of binding of small G proteins of the Ras family to its N-terminus and its phosphorylation the Raf is activated [8]. It plays an important role in confronting the environmental stress in plants, *i.e.*, it undergoes MAP Kinase signal cascade as it plays a role in gene expression, programmed cell death, cell division, cell proliferation and metabolism also. MAPK cascade activates abiotic stresses such as cold, salt, touch, wounding, heat, UV, osmotic shock, heavy metals, etc. When the plant gets the stimulus, the cell wall receives the signal through cell wall receptors and then transduce the signal through histidine kinase which activates ROS results in the activation of MAP Kinase signal transduction pathway and various transcription factors like DREB2A which regulates further release of antioxidants SOD, GSH in order to balance the concentration of ROS and leads to the programmed cell death, cell division and metabolism (Fig. 1). the particular plant gives response in order to survive under harsh conditions. The specific MAPK cascade reliability can be mediated by shared docking domains, scaffold proteins and anchoring proteins. In this cascade extracellular mitogen bind to the cell wall receptors and it allows Ras (small GTPase) to swap its GDP to GTP and then it activates MAP3K (Raf) and then MAP2K and activates up to MAP Kinases.

Role of MAPKs in biotic stress

In *Arabidopsis* 20 MAPK-like genes have been identified. Specific MAPKKK, MAPKK, MAPK proteins have been identified associated with the MAPK signaling cascade which results in the activation of defense related genes *via* transcription factors. *Ralstonia solanacearum* is the causal agent of bacterial wilt, is one of the vital bacterial disease worldwide. Many diverse plant species, including many important agricultural crops such as potato, tomato, banana, pepper, and trees such as eucalyptus are affected by this vascular pathogen [9]. The RRS1-R gene for resistance against *Ralstonia solanacearum* interacts with special conserved sequences (W box) in the promoter to induce gene expression after sensing the avirulence elicitor of bacteria.

In tobacco, 2 MAPKs *i.e.*, SIPK (salicylic acid induces protein kinase, similar to MPK6 of *Arabidopsis*) and WIPK (wound induced protein kinase, similar to MPK3 of *Arabidopsis*) are activated when TMV infection occurs in the presence of the N resistance gene [10]. The activation of both the MAPKs are by different activation mechanism. The SIPK gene positively regulates programmed cell death also. In tomato, calcium influx and phosphorylation events lead to interaction between Avr9 and SIPK, WIPK. MAP Kinase independent of the oxidative burst this has been proved by blocking SIPK and WIPK activation, which do not abolish Cf-9-Avr9-dependent ROS production. Innate immunity gene for gene resistance and mechanical stress responses operate through MAPK signaling pathways in plants, but how these kinases (which are multifunctional) operates still uncleared.

Regulation of Reactive oxygen species

ROS are a group of free radicals, which includes hydrogen peroxide [H_2O_2], hydroxyl ion [OH^-] etc. ROS is produced in chloroplasts, mitochondria, peroxisomes, plasma membrane, endoplasmic reticulum and cell wall under stressful as well as non-stressful conditions [11]. ROS in MAP Kinase signal transduction pathway plays a dual role through the ABA pathway and it is beneficial as well as non-beneficial depending on their concentration. If it is produced in higher amount than it eventually undergo PCD and if it is lower than the plant doesn't survive under adverse conditions. ROS regulates appropriate signal through redox sensitive protein, protein phosphorylation, Ca^{+2} mobilization and gene expression and Abiscisic acid induces the production of ROS (hydrogen peroxide) in order to prevent the water loss due to stomatal closure by the activation of calcium permeable channels in the plasma membrane. ROS regulates by activating histidine kinase and the transcription factors like to say DREB2A [12]. It has been reported that it plays an important role in drought conditions as plant can sense the condition of drought through ABA signal transduction. According to pharmacological studies, it has been reported that cadmium and copper induce the MAP Kinase activation by different ROS generating systems.

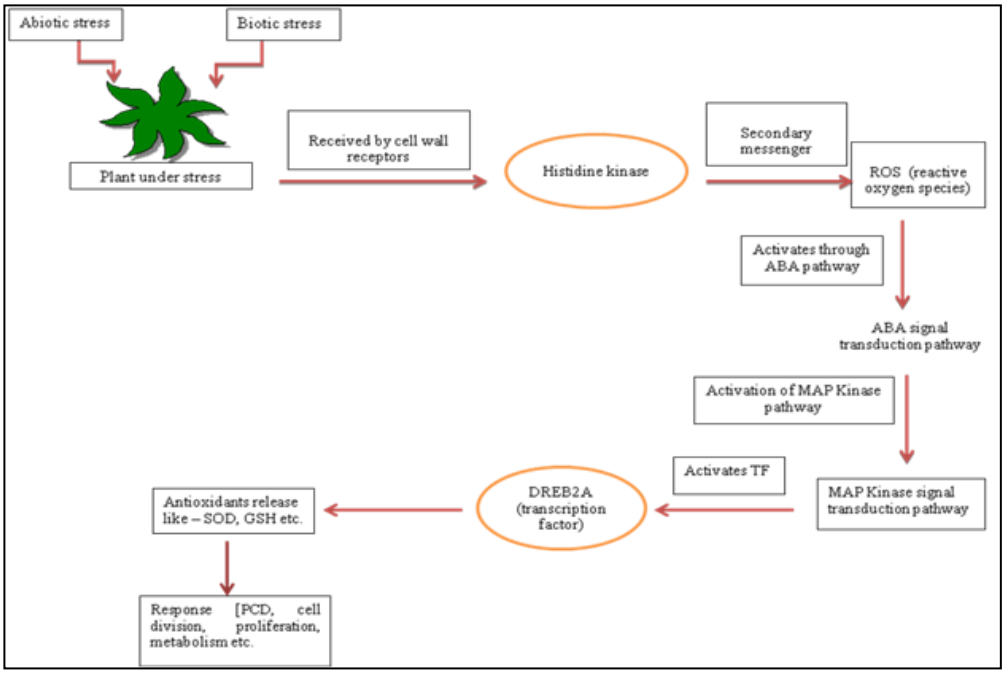

Fig 1: Generic pathway for the regulation of MAPK signalling pathway in abiotic and biotic stress

Conclusion

The information we gathered from the above article is how to overcome such environmental stress by gene manipulation and also we get to know about the role of regulation of ROS in mitogen activated protein kinases pathway. All these studies provide convenient knowledge about this important pathway which is a useful tool for further crop improvement in this era of global climate change. The "in silicobiology "helps out to get all the important databases like the particular genes which is functioning under stressful conditions and the further regulation of ROS. MAPK, MAP2K, MAP3K plays an important role in the regulation of ROS under environmental stresses and furthermore, research is going on in two plant systems that is rice (*Oryza sativa*) and Arabidopsis.

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