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Reactive Oxygen Species (ROS): Regulation in Crop Plants during Abiotic Stress Response

Kasinathan Rakkammal*, **Subramani Pandian and Manikandan Ramesh**

Departments of Biotechnology, Alagappa University, Karaikudi, Tamil Nadu, India

***Corresponding author:** Kasinathan Rakkammal, Departments of Biotechnology, Alagappa University, Karaikudi, Tamil Nadu, India, Tel: 914565225215; E-mail: roczbiot7@gmail.com

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Abstract

Plants often experience with the various abiotic stress in nature. Abiotic stress such as drought, heat, cold, salinity and heavy metal etc., influences the plant growth as well as yield. ROS act as a key player in complex signaling network of plants which responses to various stresses. To summarize, the role of ROS in stress response and defense mechanism to environmental adaptation.

Keywords: Abiotic stress; Reactive oxygen species; Antioxidants; Redox; Toxicity

Introduction

Recent days, plants are subjected to various environmental stresses which influence the growth and yield of the plants. Generally, plants are sessile due to the various environmental factors resulted in the complicated protected mechanism of plants were evolved [1]. To deal with the stress condition, they activate many stress-responsive genes and synthesis of functional proteins to tolerate the stressed environment. Plants have undergone stress they generate the Reactive Oxygen Species (ROS), which includes H_2O_2 peroxidation and lipid peroxidation (MDA content was increased). Generally, plants produced a small amount of ROS (Reactive Oxygen Species) such as superoxide radicals (O^{2-}), Hydroxyl Radicals (OH^{-}) Hydrogen Peroxide (H_2O_2) and it was easily scavenged by enzymes. The abiotic stress leads to overproduction ROS in plant cells which is highly reactive and toxic to nucleic acids, proteins and lipids etc., trigger the cell damage and death [2].

Plants expand to develop enzymatic and non-enzymatic system protect themselves to oxidative stress and maintains the low-level ROS signal transduction [3]. Under normal condition plants produced a small amount of ROS continuously, they are scavenged by the antioxidant mechanism so that they do not cause any negative effect on plants. In a stressed condition, ROS highly accumulated in the cell cytoplasm leads to cell death.

The level of ROS controlled by two ways. In that the first one is ROS-scavenging antioxidant enzymes such as Superoxide Dismutase (SOD), Catalase (CAT), Ascorbate Peroxidase (APX), Glutathione Peroxidase (GPX), Glutathione Reductase (GR), Monodehydroascorbate Reductase (MDHAR) etc,. Another one is non-enzymatic antioxidants includes carotenoids, tocopherols, GSH and flavonoids etc,. [4]. These antioxidative systems prevent ROS production to reduce the stress effects on plant metabolism by ROS-homeostasis and Alternative Oxidases (AOX). The overall mechanism of ROS depicted in Figure 1.

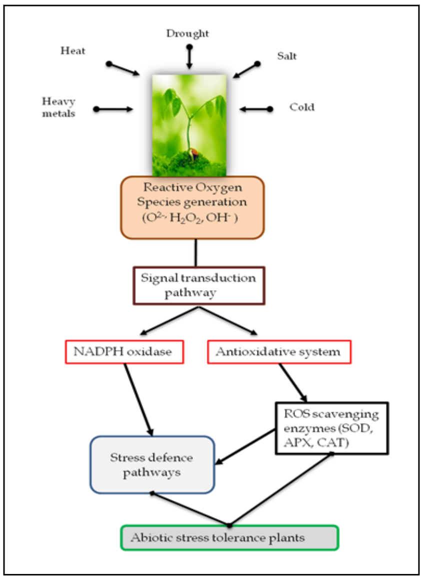

Figure 1: Plants in stressful condition ROS (O^{2-}, H_2O_2, and OH-) are generated in plant cells.

Redox homeostasis

Plants in stressful condition ROS (O^{2-}, H_2O_2, and OH^-) are generated in plant cells (Ex: NADPH oxidase in cell membrane) which act as the signals for the activation of defence pathways and antioxidative system [5]. The antioxidative system produces ROS scavenging enzymes including SOD-Superoxide Dismutase, CAT-catalase, APX-Ascorbate Peroxidase, GR-glutathione reductase, GPX-guaiacol peroxidase [6].

Typically in plants, continuous energy conversion has occurred in the chloroplast and mitochondria. The energy conversion is called "redox" reaction because it occurs in the precise environment [7]. In this, process various ROS and antioxidants were generated and transferred which involved in the plant metabolic regulation and signalling. Under the adverse environmental condition, defects occur in the cellular network redox signals are generated to elicit a specific response at various level of regulation in different subcellular compartments [8]. Hence, ROS and redox cues were produced under the stressed condition to control the metabolic processes done which convert and distribute energy, optimize cell functions, and activate adaptation response to control whole plant signalling pathways. The information-rich redox antioxidant buffers such as glutathione, ascorbate, carotenoids which affects the cellular components. Antioxidants regulate the gene expression associated with environmental stress and increase the defence activity to produce ROS and redox state [9].

Regulation of NADPH oxidase and antioxidative system in food crops

RBOHs (Respiratory Burst Oxidase Homologs) also known as NADPH oxidase is well studied enzymatic ROS in plants. It is a key player in the regulation network of ROS signalling including plant growth and development, stress response and adaptation, symbiotic interaction with microbes [10]. In drought stress, NADPH oxidase activity was increased and showed the high-temperature stability and salt-tolerant. Maize seedlings exhibit the increased NADPH oxidase activity after treatment with ABA and Ca^{2+}. In rice, nine RBOH genes (OsRBOHA-OsRBOHI) were identified and they showed distinctive expression in various stresses [11].

The antioxidative system contains enzymatic and non-enzymatic components which involved in ROS generation and maintain the ROS homeostasis. Numerous studies reveal the roles of antioxidative components in ROS homeostasis. Rice has eight APX genes including cytosolic APXs (OsAPX1 and OsAPX2), peroxisomal APXs (OsAPX3 and OsAPX4), mitochondrial APXs (OsAPX5 and OsAPX6), and chloroplast APXs (OsAPX7 and OsAPX8). Among these, cytosolic APXs play a pivotal role in abiotic stress resistance [12,13]. Impressively, a mutant study done in rice by cytosolic APXs (APX1 and APX2) gene silencing resulted in the changes in redox status elevated H_2O_2 levels, glutathione and ascorbate leads to alterations in the ROS signalling network and effecting the mutant also has the capacity to deal with abiotic stress related to non-transformed plants. There is eight-SOD gene in rice, such as copper SODs (cCuZn-SOD1 and cCuZn-SOD2), iron SODs (Fe-SOD2 and Fe-SOD3), plastidic SOD (pCuZn-SOD), manganese SOD (Mn-SOD1) and CuZn-SOD-like (CuZn-SOD-L). Overexpression of Mn-SOD1 in transgenic rice exhibit low mitochondrial O_2-and decreased the stress induction of OsAOX1a/b. Similarly, the Overexpression of OsTRXh1 in rice produce less amount of H_2O_2 and reduce the expression of salt stress-responsive genes during salt stress [14,15]. It also encodes h-type TRX to regulate the apoplast redox state and involves in the plant development and stress [16-26].

Conclusion

We strongly believed that regulation networks of ROS balancing the ROS production and scavenging pathways. Numerous reports are available in ROS and the activity of antioxidant enzymes were increased during stressed conditions. They demonstrated that the ROS associated genes and exhibits its role in the regulation of expression and activity of ROS scavenging enzymes. ROS regulation is the key player for the acclimation response of plants to modify theirmetabolism to survive during environmental stress. It enhances the stress resistance under real agricultural field conditions and protects global food crop production.

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Conflict of Interest

The authors don't have any conflict of interest to declare.

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