

Redox regulation of plant stress and development

The redox state of many proteins and small metabolites in cells is directly linked to the cell environment, developmental stage and levels of reactive oxygen species (ROS). Redox regulation is also tightly integrated with many important signal transduction mechanisms of cells, such as protein phosphorylation, calcium signalling and protein degradation. Any change in ambient condition(s), a developmental signal, the initiation of a biotic and/or abiotic stresses and/or a change in the metabolic state of the cell, could therefore alter the levels of ROS (or redox), which in turn will alter the redox state of many proteins (or cellular ROS levels) causing or triggering a balanced and regulated cellular response (Figure 1; Jones & Sies, 2015; Mittler et al., 2022; Sies & Jones, 2020). As many ROS-producing proteins such as respiratory burst oxidase homologs (RBOHs), as well as many ROS-scavenging enzymes and pathways such as glutathione reductases and the Foyer–Asada–Halliwell pathway, require NADPH and/or NADH that are important redox coins in cells, the interplay between ROS and redox is tightly regulated and impacts the redox state, structure and function of important proteins such as transcription factors, kinases/phosphatases, channels, multiple enzymes and more. Recent advances in redox proteomics, computational network analyses, imaging technologies and modelling have shed new light on how redox regulation is involved in many important processes in plants, associated with responses to environmental stresses, pathogens and developmental programs.

With the overall goal of increasing the awareness of the plant research community to these developments, as well as to the key role ROS and redox play in regulating plant metabolism, signalling, responses to the environment, and growth and development, we

organized this Special Issue focused on 'Redox regulation of plant stress and development'.

Included in the special issue are in-depth reviews and research papers that cover a wide array of subjects. Mittler and Jones (2024) outline the many links between redox and ROS and describe the 'redox code' of plants and its involvement in linking different organelles, cells and even different plants. Myers et al. (2024) discuss plant systemic responses and plant systemic acclimation to stress and highlight the role ROS signalling and the 'ROS wave' play in these processes. Pliskova et al. (2024) describe how ROS and redox regulate gene expression and stress memory via altering the activity of histone-modifying enzymes, chromatin remodelers and DNA methyltransferases (i.e., epigenetic regulation of chromatin expression) by oxidative posttranslational modifications. Alazem and Burch-Smith (2024) discuss how ROS and redox modify intercellular trafficking through plasmodesmata during stress and development. They further highlight processes by which viruses alter plasmodesmata trafficking via altering the cellular levels of ROS and redox. Goggin and Fischer (2024) review the important, and many times neglected, subject of singlet oxygen metabolism and signalling. They highlight compartments such as the chloroplast, mitochondria, peroxisomes, cytosol and the nucleus, as sites of enzymatic and nonenzymatic production of singlet oxygen and discuss the role of this ROS in regulating processes in these compartments. Hoh et al. (2023) discuss the importance of reversible oxidation and reduction of protein thiol groups for the regulation of photosynthesis. They focus on the less studied aspect of redox control of thylakoid lumenal enzymes. Ali and Muday (2024) review the multiple and highly important roles of redox and ROS in regulating plant development and reproduction. They focus on ROS

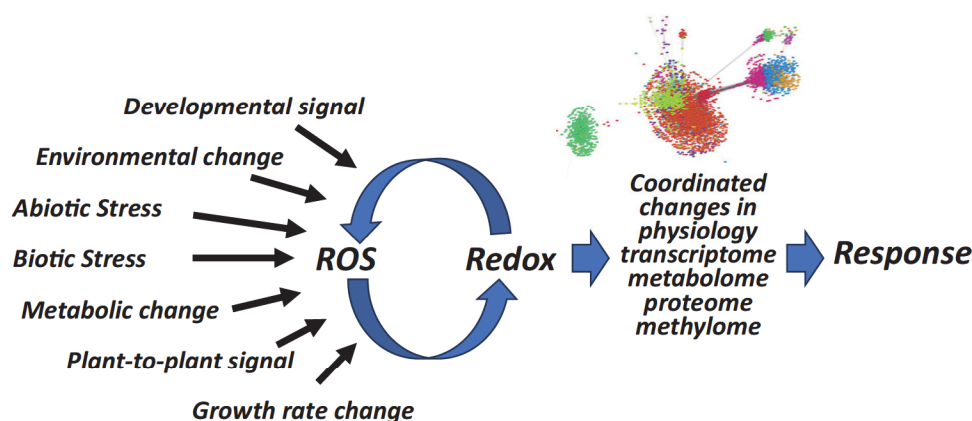


FIGURE 1 The relationship between reactive oxygen species and redox plays a key role in decoding internal and/or external changes in the plant environment and adjusting plant physiology, metabolism and molecular/biochemical responses to form a response to them.

production and scavenging during reproductive stages from gametophyte development to completion of fertilization and address the effects of elevated temperatures on these processes. Niekerk et al. (2024) review the multiple effects of heavy metals on ROS and redox regulation of stress responses and signalling with a focus on mitogen-activated protein kinase cascades. Huang et al. (2024) take an in-depth view into thiol-based posttranslational modifications of proteins. They highlight the role of thiol sulfinic acid modifications, which are generally thought to be irreversible and less significant than other modifications, revisiting this narrow perspective and shedding new light on the redox regulatory roles of sulfinic acid modification in plant stress signalling. Shamim et al. (2024) discuss the role of ROS and redox signalling in the different phases of plant nematode interactions and how this role affects the outcome of the infection process.

Two research papers are also included in the Special Issue: Timm et al., (2024) address the central role of thioredoxins in redox regulation. They provide evidence for additive negative effects of single and combined thioredoxin deficiencies on growth and photosynthesis of plants. Ahmed et al. (2024) developed novel genetic tools to determine whether aquaporins facilitate the diffusion of H₂O₂ through the plasma membrane in living plant cells. They used a heat shock-inducible promoter to co-express the fluorescent H₂O₂ sensor HyPer and aquaporins in plant cells and determined the role of specific aquaporins in facilitating H₂O₂ diffusion.

We hope that interested readers will find the Special Issue to be enticing and informative and that reading it will enhance the awareness of readers of the important role ROS and redox play in plant biology.

KEYWORDS

environmental stress, metabolism, reactive oxygen species, signalling

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