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ROLE OF ANTIOXIDANTS IN MITIGATING PLANT STRESS

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CHAPTER

8

Enzymatic and nonenzymatic antioxidant defense in plants under cold or chilling stress

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Abbreviations

ROS	reactive oxygen species
CS	chilling/cold stress
DNA	deoxyribonucleic acid
SOD	superoxide dismutase
CAT	catalase
POX	peroxidases
RNS	reactive nitrogen species
GR	glutathione reductases
DHAR	dehydroascorbate reductases
MDHAR	monodehydroascorbate reductases
GPX	glutathione peroxidases
APX	ascorbate peroxidases
MDHA	monodehydroascorbate
DHA	dehydroascorbate
NAD(P)H	nicotinamide adenine dinucleotide phosphate hydrogen
GSH	glutathione
GSSG	glutathione disulfide
ASA	dehydroascorbic acid
PC	phytoalexins
UV	ultraviolet
AA	ascorbic acid
ROO	peroxyl radicals
NPQ	nonphotochemical quenching

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ABA abscisic acid
IPCC intergovernmental panel on climate change
TCA tricarboxylic acid
CSP cold shock protein
LEA late embryogenesis abundant
RNA ribonucleic acid
ETC electron transport chain
MDA malondialdehyde
AsA-GSH ascorbate-glutathione

8.1 Introduction

Exposure to temperatures between 0 and 20°C that do not approach freezing is known as chilling, and it has long been recognized as a major stressor on plant growth, especially for agricultural species that originate in tropical or subtropical regions (Boyer, 1982; Zahra et al., 2021). While cooling stress can be detrimental, there are some processes in which it is advantageous. For instance, in many plant species, cooling is an essential environmental signal during vernalization, the process that triggers the change from vegetative development to blooming (Penfield et al., 2021). Stratification, or the chilling of ingested seeds, is frequently necessary to break seed dormancy (Mbi et al., 2022). Furthermore, cooling is essential for causing buds to become dormant in the fall (Heide & Prestrud, 2005). Through a process called cold-hardening or cold acclimation, chilling also helps some species acquire a resistance to freezing (Ruelland et al., 2009). All plants, however, view their first encounter with cooling or a drop in temperature as a stressor. Certain plants have the ability to adjust to this stress and acquire a tolerance to cold, but in other species, the exposure to stress causes certain developmental reactions (Table 8.1).

Because they live in stationary environments, plants are subject to a variety of abiotic challenges, such as pesticide residues, heavy metals, salinity, drought, nutritional shortages, and fluctuations in light intensity. Global crop output and food security are severely hampered by these pressures (Wang & Frei, 2011). Abiotic stresses negatively impact gas exchange parameters, electron transport processes, photosystem function, chlorophyll production, and other relevant variables, which ultimately reduces photosynthetic efficiency (Muhammad et al., 2021). Plant productivity is severely restricted by low temperature or chilling stress, which hinders photosynthetic processes and other metabolic activities (Allen & Ort, 2001). Chilling stress interferes with a number of photosynthetic processes, such as thylakoid electron transport, transpiration rates, stomatal conductance, and the carbon reduction cycle (Zahra et al., 2021). Understanding the complex dynamics that lead to these regulatory disruptions is a significant problem. Low temperatures, for example, cause stomatal closure by impairing the guard cell's ability to operate, which modifies the CO_2 concentrations inside the leaf and decreases RUBISCO activity (Allen & Ort, 2001). Plants adapt their physiological and biochemical mechanisms to withstand harsh circumstances in response to temperature stress. Studies have shown that exposure to low temperatures, or "chilling," frequently causes photodamage (Tambussi et al., 2004). Low temperatures and strong light levels can interact to