Plant Stress Tolerance

Molecular Mechanisms and Breeding Strategies

VOLUME ONE

Edited by Jen-Tsung Chen

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Plant Stress Tolerance

Plant Stress Tolerance: Molecular Mechanisms and Breeding Strategies, *Volume One* provides effective ways for organizing precision and sustainable agriculture. The methods include the use of advanced molecular techniques covering multiple omics, high-throughput technology, computational biology, epigenetic manipulation, and CRISPR genome editing. These methods can advance the development of high-yield, high-quality, and stress-resilient crops that meet the requirements for supporting global food and nutrition security.

The book proposes strategies for omics-assisted and speed breeding techniques, exploring molecular mechanisms of plant abiotic stress caused by temperature, drought, salinity, and various pollutants. These are uncovered by quantitative trait loci analysis and mapping, genomic selection, functional genomics, multiple omics, high-throughput sequencing, and high-throughput phenotyping, and are integrated into the various systems of crop improvement.

Plant Stress Tolerance: Molecular Mechanisms and Breeding Strategies, *Volume One* presents emerging and comprehensive knowledge and is an ideal reference for students, researchers, teachers, and professors. It inspires ideas for investigations into the fields of plant stress physiology, plant functional genomics, plant multiple omics, plant genetic engineering, systems biology, and crop breeding.

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9.1 INTRODUCTION

According to FAO-STAT (http://faostat.fao.org) and Verisk Maplecroft (https://www.maplecroft.com) (Bita and Gerats, 2013), climate change, specifically an increase in ambient temperatures, is expected to have a major impact on plant growth and development. This will lead to a catastrophic reduction in crop productivity, causing severe famine and limiting global food security. The Intergovernmental Panel on Climate Change report states that the combustion of fossil fuels and the resulting greenhouse gas emissions are responsible for the buildup of atmospheric concentrations of greenhouse gases that absorb infrared radiation reflected from the earth's surface. Forecasts suggest that global air temperatures will rise by 0.2°C on average every 10 years, with a possible increase of 1.8–4.0°C by 2100. The rise in temperature above a threshold level for a length of time long enough to permanently harm plant growth and development is commonly referred to as heat stress. Heat shock or heat stress is often defined as a brief increase in temperature, typically 10–15°C above ambient temperature. The severity, duration, and rate of increase in temperature play intricate roles in the effect of heat stress on plants. The occurrence and length of high temperatures (HTs), whether during the day or at night, determine how heat stress manifests in different climate zones. The ability of a plant to flourish and produce commercially viable produce in HTs is known as heat tolerance. Heat stress profoundly affects essential biological processes, either directly or by modification of the surrounding ecological milieu. Of them, plants, being dependent on their environment, have significant difficulties in enduring HTs. HT stress thus seriously impairs the growth and developmental trajectories of plants, frequently with irreversible effects. Plant growth, development, physiological processes, and yield are all affected by heat stress in a variety of ways that are frequently detrimental (Figure 9.1 and Table 9.1).

The overproduction of reactive oxygen species (ROS), which causes oxidative stress, is one of the main effects of heat stress (Hasanuzzaman et al., 2012, 2013). Under a variety of environmental stress situations, including HTs, plants constantly fight for existence. A plant may withstand heat stress to some degree by internal physiological changes and typically by generating signals that alter metabolism. HTs lead to the inactivation of chloroplastic and mitochondrial enzymes including decline in protein synthesis, protein degradation, and a breakdown in membrane integrity (Howarth, 2005). Moreover, heat stress disrupts the arrangement of microtubules, leading to alterations such as splitting or elongation of spindles, formation of microtubule asters, and microtubule elongation (Smertenko et al., 1997). Starvation, growth inhibition, decreased ion flow, the generation of hazardous chemicals, and ROS are the final results of heat stress injuries (Schoffl et al., 1999; Howarth,

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