Chapter 1

Introductory Chapter: Climate Changes and Abiotic Stress in Plants

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Additional information is available at the end of the chapter

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1. Climate change

Climate change is a problem with the highest priority facing the mankind today, influencing agricultural production worldwide. According to IPCC [1], human activities are the main factor for changes that are unique over decades to millennia. Gas emissions have increased since 1950s, reach the highest level nowadays than ever. Atmospheric concentration of CO_2 was less than 300 ppm from the beginning of human civilization to 1900. The present level at about 400 ppm was not reached in more than 400,000 years. The period from 1983 to 2012 was the warmest 30-year period of the last 1400 years in the Northern Hemisphere. The Earth's average temperature increased for 1.4°C in twentieth century and is predicted to increase about 11.5°C in twenty-first century. With more climate disruption by human activities, average temperature is predicted to rise in twenty-first century, heat waves are going to be more frequent and last longer, as well as occurrence of unevenly distributed precipitation in many areas. Warming and acidification of oceans will continue, followed by rising sea levels due to the melting of polar ice, and additional rainfall leads to flooding. Climate change caused by humans is significantly faster than natural global climate change during the past millions of years and most plants cannot naturally adapt according to fast changes of ecosystems caused by global warming. Temperature increases of about 4°C in late twentieth century, is reducing wheat, rice, and maize global production and with increasing food demand, seriously affecting food security. The consequences of global warming on crop production became a major task for researchers in the past decades. Also, climate change affects a number of days when plants can grow, by their decreasing of 11% until 2100. Simultaneously, extreme temperatures and rainfalls, lowering of available water, and changes in soil quality are expected to make difficulties for plants to grow and survive. Nevertheless, plants will be exposed to different abiotic and biotic stresses at the same time and their responses will be more complex with overlapping of different stress response pathways.

2. Abiotic stress

Abiotic stress is defined as environmental factors that affect plants and reduce growth and yield below optimum levels. Plant abiotic stress factors include extremes in temperature, water, nutrients, gasses, wind, radiation, and other environmental conditions. Plant responses to abiotic stresses are dynamic and complex; they are both elastic (reversible) and plastic (irreversible). Since the plants are exposed to a combination of different stresses, responses are more complex and different stress pathways overlap [2]. In "Adapting Crops to Climate Change," the authors suggest "the major abiotic stresses expected to increase in response to climate change are drought, heat, salinity, and inundation" [3]. Nowadays, tolerance to drought and heat, and water use efficiency are receiving the most attention in breeding programs worldwide.

2.1. Drought

Drought is expected to have the highest influence on crop productivity decrease in the frame of upcoming global warming. Predictions are that 30% of land will be exposed to extreme drought by the end of twentieth century [4]. Consequently, demand for irrigation will considerably increase in future, since about 70% of water worldwide is used in agriculture. Limited resources of irrigation water will require careful management to obtain crop production for food and feed. Various plant drought responses are classified into three categories, more than 50 years ago: drought escape, drought avoidance, and drought tolerance [5].

Plants escape drought by fast phenological development, completing their life cycle before the water deficit occurs and it is distinct from drought resistance. Drought avoidance is based on plant maintenance of water status through improvement of water balance by increased water uptake by deeper roots and/or reducing water loss by increasing leaf waxiness. Drought tolerance involves biochemical mechanisms activated after stress to enable plant to maintain functional growth under low available water. Osmotic adjustment is a typical physiological mechanism for dehydration tolerance or turgor maintenance by accumulation of osmoprotectants, ABA or increase of antioxidative and other protecting mechanism. Usually, plants combined different drought responses, and their adaptation and productivity depend on balance between all three strategies. Drought tolerance is a quantitative, complex trait, under genetic control and significant influence of the environment. Despite the increasing knowledge on plant stress responses and the advancement of "omics" technologies to screen number of genes involved in drought response, the improvement in breeding for drought tolerant crops is relatively modest.

3. A system biology perspective

Recent achievements in biotechnology have significantly increased possibilities for gene discovery and functional genomics. Comprehension of gene action is a major challenge in postgenomic era, since many of the roles of particular genes are unknown, they are inferred and associated with other known genes, and that provide a better understanding of biological functioning. High throughput "omics" technologies are enabling the identification of new genes and their function. Three systematic approaches or "omics" improved our knowledge of the complex mechanisms that regulate genes and networks in stress response through adaptation and/or tolerance. The first "transcriptomics" includes the analysis of coding and noncoding RNAs, and their expression profiles. The second one "metabolomics" analyzes a large number of metabolites. The third one is "proteomics" in which protein and protein profiles offer a widening of knowledge about regulatory networks. The combination of data on gene expression, protein synthesis, and production of small cell metabolites give better overview of plant response to drought-stressed environment. System biology examines all factors in plants in response to environmental stresses that help in better explanation and understanding of involved mechanism. Integration of "omics" technologies allows identification of molecular study of abiotic stress signaling and application of biotechnology in crop production in future [6, 7].

4. Perspectives

As climate change includes crop adaptation to new environmental conditions, breeders are challenged to breed for new unpredictable conditions, and to consider the genetic potential of past breeding work. "Traits that may not have been as attractive 10, 15 or 20 years ago are more important today because with these new techniques and abilities breeders are able to look at what's in their library and although they maybe couldn't tease out a specific trait previously, today they are able to" [3]. Global warming indicates necessity to look for crops that are more convenient for new environment, not only to focus on adapted crops and attempt to improve their tolerance to drought, cold, heat, or any other emerged conditions. "If you want to talk about real sustainability it is not just about making crops that are currently the emphasis…better, it's also thinking about the big picture and what other crops we are going to need to make better to fit into those cropping systems" [3]. Progress in breeding for improved drought tolerance will be accomplished by integration of conventional breeding with physiology and genomics [8]. Large amount of available data obtained from "omics" technologies put a new challenge for agricultural bioscience in their analysis and practical applications. Developing tools integrating environmental stressors and diverse genetic backgrounds, together with numerous levels of analysis will help in better understanding of biological processes in plants under stress. Although new technics can be used to predict some aspect of plant responses to stress, there is still a large gap between huge amount of available data and our understanding of biological networks and phenomena. It required having close collaboration of agronomists, molecular biologists, biochemists, and computer scientists in order to provide those answers [9].

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