Focus on Climate Change

Among the most significant and daunting challenges facing science and society this century is predicting the response of plants, and the communities and ecosystems to which they belong, to global climate change. Rapid environmental changes have long been recognized as powerful driving forces for positive, directional selection as a main cause of adaptation to changing conditions. Directional selection is reliant on the availability of genetic diversity for selection to act upon. However, human-caused environmental change is currently occurring at unprecedented rates. These changes are so rapid that for most plants, new adaptive mutations are powerless to respond on a relevant time scale, leaving these organisms reliant on existing genetic diversity to enable adaptation. For some species, extant genetic diversity may be sufficient to support significant adaptive responses, but others (i.e. those that have gone through “population bottlenecks” in their recent evolutionary history) may lack sufficient genetic diversity to respond successfully to rapid environmental change. Moreover, in the case of very long-lived organisms that reach reproductive maturity slowly, such as many tree species, environmental change may be occurring too rapidly to allow the expression of the genetic diversity that may exist within the species for adaptation. Thus, the capacity of organisms to respond to the current challenges of exceptionally rapid environmental change is defined in large part by existing genomes, which will dictate the capacity of organisms to resist rapidly changing conditions or govern the capacity to change in response to perturbations in ways that maintain overall organism integrity.

In addition to being affected by rapid changes in their physical environment, plants, and the communities and ecosystems to which they belong, also have the potential to drive important feedbacks on the physical environment. For example, the increase in net primary productivity of many terrestrial ecosystems in response to increasing atmospheric carbon dioxide (CO₂) serves to remove a greater amount of CO₂ from the atmosphere, whereas the accompanying decrease in evapotranspiration from plants may feedback on local climate to reduce precipitation, thereby constraining net primary productivity. Climate change can also alter natural species abundance and distribution or favor invasive species, which in turn can alter ecosystem dynamics and the provisioning of ecosystem services.

This issue of Plant Physiology focuses, through a series of invited Updates and contributed research papers, on an array of issues and recent advances pertinent to our understanding of the response of plants to elements of rapid climate change. Anderson et al. (2012) set the stage by using ecological and evolutionary theory to discuss the relative roles of migration, phenotypic plasticity, and adaptation in the response of plants to global change. Climate change will also impact biotic communities and the interaction of plants and insects, which will have implications for both natural and agricultural communities. Current knowledge of the interplay of rising atmospheric CO₂ and temperature on plant-insect interactions is updated by De Lucia et al. (2012), while Jamieson et al. (2012) discuss the consequences of warming and altered precipitation on plant-insect interactions.

In 2012, the United States experienced the most severe and extensive drought in the past 25 years, which resulted in maize (Zea mays) yields approximately 25% lower than expected based on the long-term trend line and soybean (Glycine max) yields approximately 14% lower than expected (U.S. Department of Agriculture, National Agricultural Statistics Service; http://www.nass.usda.gov/Statistics). This recent drought serves as a powerful reminder of the effect that weather and climate can have on food production. In the future, precipitation is likely to be more variable, with increasing extremes in the occurrence and magnitude of both droughts and flooding. Remarkable progress in understanding the developmental, morphological, physiological, and molecular mechanisms of flooding tolerance have enabled breeding of high-yielding, flood-tolerant rice (Oryza sativa) varieties (Bailey-Serres et al., 2012). These advances in breeding crops for flooded environments provide a framework for adapting crops to other aspects of global change, including rising temperature, CO₂, and pollutant levels. In their Update, Lobell and Gourdji (2012) estimate the impact of recent climate change on global food production, and describe the range of potential outcomes of future climate change on crop production. They also show that many countries have average temperatures that currently exceed the optimal temperature for crop production, highlighting the importance of adapting crops to a warmer environment. The physiological processes and traits for which there is evidence that genetic improvement could improve wheat adaptation to heat stress are discussed by Cossani and Reynolds (2012).

Current and future climate change threatens biodiversity, crop productivity, and other ecosystem services. This Focus issue addresses aspects of understanding and adapting plants to impending climate change. While our understanding of plant molecular, biochemical, and physiological responses to individual elements of climate change, such as rising atmospheric
CO₂, temperature, or flooding is improving, understanding the complex interactions that plants and crops will face in the future remains a significant knowledge gap. We hope that this special issue will encourage future research in understanding and adapting to climate change, which will certainly continue to modify natural and managed ecosystems. The issue highlights the range of scales that experiments must address, from molecular to ecological and evolutionary, to develop the knowledge needed to tackle the many challenges from anthropogenic climate change.

LITERATURE CITED


Donald R. Ort
Editor-in-Chief
Plant Physiology

Elizabeth Ainsworth
Monitoring Editor
Plant Physiology