Preface

Producing a road map that enables plants to cope with future climate change

If the worst predictions of climate change are correct, global warming could cause changes in temperature at a rate unmatched over the last 50 million years, as well as an increase in the frequency and severity of extreme weather events. The potential impact of such events on food production can already be seen in the effects of the severe droughts in Australia in 2007–8, Russia in 2010, and South-East China in 2013, all of which contributed to steep rises in crop commodity prices and helped push food security to the top of the global agenda.

As well as dealing with a changing and increasingly extreme climate, agriculture will have to meet the demands of a growing population and increasing *per capita* consumption while contending with rising energy costs, the approach of peak oil, the use of crop products for biofuel and renewable raw materials, competition for fresh water and land, soil degradation, and pollution. It will also be required to do its bit to reduce greenhouse gas emissions. Plant breeding and the sciences that underpin it will have a major part to play in meeting these challenges, and this volume comprises a series of papers from leading researchers in the field.

The challenges facing agriculture are described in detail by Bryan McKersie, who proposes that a research plan is required to integrate agronomic and genetic approaches that incorporate biotechnology, genetics, physiology, breeding, agronomy, and cropping systems. He considers that such an integrated interdisciplinary approach will have the greatest probability of success. An obvious problem that climate change presents for plant scientists and breeders is that new crop varieties must have physiological traits that are suited to future rather than present conditions. Here, modelling will play an important part and this crucial role is reflected in the prominence of articles concerning different aspects of crop modelling in this volume. For example, Ramirez-Villegas *et al*. (2015) review the use of models for assessing the potential benefits of genotypic adaptation to projected climate change, while Rötter *et al*. (2015) consider the potential of crop simulation modelling for ideotype breeding in order to accelerate the delivery of future cereal cultivars for different environments. Martre *et al*. (2015) use the process-based wheat model, *SiriusQuality2*, to identify candidate traits for improving grain yield and grain protein concentrations in wheat that are influenced by climate change and nutrition. In addition, Stratonovitch and Semenov (2015) use the Sirius wheat model to quantify yield losses resulting from heat stress and to optimize wheat ideotypes for predicted climate scenarios.

Continuing on the theme of plant responses to temperature extremes, Frederiks *et al*. (2015) and Zheng *et al*. (2015) consider freezing and frost damage, which can cause huge losses to wheat and barley crops that are grown through winter for harvest in the spring. Ironically, these abiotic stresses may become more of a problem as future temperature changes affect the rate of wheat and barley development. Another important abiotic stress that is predicted to become more of a problem in many areas is drought. Using crop modelling approaches, Heinemann *et al*. (2015) identify drought tolerance as a key target for the Brazilian upland rice breeding programme.

Dockter and Hansson, 2015 review the genetic control of barley architecture, focusing on culm length, an example of a complex trait controlled by multiple genes. The availability of modern genetic resources, in this case in the form of mutants and genome sequence data, and the development of high-throughput phenotyping is making such complex traits much more amenable to plant breeding. The thousands of landraces held in seed banks around the world are another important genetic resource. The potential exploitation of wheat landraces to identify traits that may be incorporated into breeding programmes for heat and drought tolerance, increased photosynthetic rate, and biomass accumulation, is reviewed by Lopes *et al.* (2015). Conservation of this biodiversity, as well as seed germination and, therefore, crop performance, is dependent on genome integrity, with deterioration in seed quality known to be associated with the accumulation of cellular damage to lipids, protein, and DNA. Waterworth *et al*. (2015) review the mechanisms that mitigate this damage and maintain seed viability and germination vigour.

The issues surrounding future crop nutrition are also highlighted in papers by Pilbeam (2015) and Baker *et al*. (2015). Pilbeam considers how soils and nutrient availability will be affected by climate change and increased atmospheric CO_2 availability, and how this knowledge might influence crop breeding programmes, while Baker *et al*. (2015) review current knowledge of mechanisms by which crops sense and respond to phosphate stress. This review highlights the importance of phosphate nutrition in the context of the immediate problem of phosphate pollution of waste water and the longer-term problem of finite and declining rock phosphate reserves. In an original research article, Comadira *et al*. (2015) demonstrate that the fecundity of the green peach aphid (*Myzus persicae*), which has a broad host range, is adversely affected by nitrogen deficiency in barley leaves. Evidence is provided showing that, although nitrogen-deficient barley leaves are rich in amino acids and sugars, they could not support the growth of aphid nymphs to adulthood. The findings presented by Comadira *et al*. (2015) not only highlight significant similarities between biotic and abiotic stress signalling cascades but also identify potential new targets for increasing aphid resistance.

Several different emerging issues are highlighted in this volume. Firstly, the role of DNA methylation in mediating gene expression changes in response to environmental signals is described by Meyer (2015). Secondly, the role of phytocystatins, a class of protease inhibitors, is highlighted in relation to the changes in cellular protein content and composition that are required for acclimation to different abiotic stresses. Our current knowledge on this topic is reviewed by Kunert *et al*. (2015), with an emphasis on how the cysteine protease/phytocystatin regulation operates in legumes. The final emerging topic considered in this volume concerns our lack of understanding of the functions of plant polyphenol oxidases. Boeckx *et al*. (2015) present evidence suggesting that polyphenol oxidase is involved in the response of plants to a range of abiotic stresses and discuss the potential opportunities that this presents for exploitation with regard to increasing stress tolerance.

Innovation is sparked at the interface between different disciplines that seek to tackle a common problem. The interdisciplinary nature of the content of this volume seeks not only to inform and inspire the reader but also to provide new information that will assist in the production of a road map to enable plant scientists to tailor plants to cope with future climate change and thrive in a sustainable manner under more challenging environmental conditions. Such endeavours are essential underpinning frameworks to support future food security. We are grateful to the Association of Applied Biologists, Africa College at the University of Leeds, and the EU-MACSUR knowledge hub for making this fusion of exciting new knowledge possible.

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