CSIRO PUBLISHING

Functional Plant Biology, 2014, **41**, v–vi
http://dx.doi.org/10.1071/FPv41n11_FO

Foreword

Developing drought tolerant crops: hopes and challenges in an exciting journey

Vincent Vadez[A,D], *Jairo Palta*[B] *and Jens Berger*[C]

[A]International Crops Research Institute for Semiarid Tropics, Crop Physiology Laboratory, Patancheru, 502 324 Telangana, India.
[B]CSIRO Agricultural Productivity Flagship, Floreat, WA 6014, Australia.
[C]CSIRO Plant Industry, Private Bag No. 5, Wembley, WA 6913, Australia.
[D]Corresponding author. Email: v.vadez@cgiar.org

Abstract. Under increasing water scarcity, food production for an increasing population is a global challenge. Maintaining crop production under limiting water supply is a common problem in agriculture, which is best addressed by the coordinated efforts of geneticists, physiologists and agronomists. This special issue is a selection of oral and poster presentations at the InterDrought IV conference, held in Perth (2–6 September 2013). These papers provide a broad, multidisciplinary view on the way to develop improved cultivars in the face of water deficit, providing the conference highlight: an integration of views from different disciplinary angles, generating constructive debate that was not buried in disciplinary silos. More specifically, the topics covered deal with the challenge of adaptation implicit in genotype-by-environment interaction, bring new perspectives on root systems and water productivity, and review the challenges and opportunities provided by crop management, genomic and transgenic approaches to cultivar improvement.

Additional keywords: crop modelling, cross-cutting issues, InterDrought, phenotyping, plant hydraulics.

Water has become a critical resource for agriculture production, as urban societies develop and the competition for water between agriculture, industrial and domestic sectors becomes more acute. This is especially the case in areas where water is already scarce, irrigation potential has reached a maximum, and crop production is constrained by limited rainfall. Climate change is adding another dimension of complexity to an already extremely complex situation. InterDrought IV provided a forum to discuss the issue of water limitation in crop production and to propose avenues to improve it under current and future climates. Here we summarise the important areas of discussion during the conference, as reflected in selected papers from this special issue.

Genotype × environment interactions (G×E)

While these are major challenges faced by pre- and breeders generally, they are of particular relevance to water-limited environments because drought scenarios vary across time and geographical scales, leading to large interactions between genotypes and environments within and between years. Typically the questions that arise are which type of drought pattern occur, how frequently (Kholová *et al*. 2013), and which adaptive traits are required where? Crop modelling has emerged in this conference as a key tool to guide us through the complexity of drought scenarios. A paper in this volume (Kholová *et al*. 2014) presents a model to predict the value of breeding for adaptive traits and the trade-offs that occur, using the example of grain and stover productivity in sorghum, adding to earlier papers on this topic (Sinclair *et al*. 2010; Vadez *et al*. 2012). An alternative approach presented at InterDrought IV is to study adaptive strategies in genetic resource collections using germplasm that evolved under low or high drought stress in order to ascertain which traits were selected for these contrasting selection pressures. This ecophysiological approach was applied to wild and domesticated *Lupinus luteus* collected along Mediterranean terminal drought stress gradients in a companion InterDrought IV special issue paper by Berger and Ludwig (2014).

Transgenics and genomics

An interesting contrast in InterDrought IV, compared with the previous meeting held in Shanghai in 2009, was the decrease in papers reporting the use of transgenic technologies to improve the adaptation of crops to drought. Blum (2013, 2014) summarises decades of research on transgenics and concludes that little progress has been made in delivering cultivars with improved drought tolerance. Drought adaptation is complex, likely to involve interaction among many genes and we interpret the reduction in papers offering transgenic solutions as an acceptance within the scientific community that there is no simple ‘magic gene’ solution for adaptation to drought. Instead, genomic selection has become an emerging breeding tool (Thudi *et al*. 2014). Of course, the issues of G×E interaction covered in the previous paragraph remind us of the complexity of drought adaptation and we suggest that genomic selection must be integrated with physiology, agronomy and other disciplines used to understand interactions in order to fulfil its potential.

Improving water productivity

Several papers in this special issue deal with increasing water productivity (Fereres *et al*. 2014; Kapanigowda *et al*. 2014). We have indeed acquired new insight on the ways to improve the water productivity of crops in InterDrought IV (Vadez *et al*. 2014), especially on the relationship between the capacity of plants to restrict water losses under high evaporative demand, and differences in the hydraulic characteristics of roots and shoots. A paper in this special issue deals with the influence of soil water holding capacity on the mediation of hydraulic and chemical signals at the plant level (Tramontini *et al*. 2014). Clearly, the hydraulic properties of plants are becoming an important research area, especially around the issue of improving water productivity.

What we have learnt on roots?

Roots have long been a desired target in cultivar improvement for drought, but are difficult to work with and have received scant attention compared with other plant organs. This special issue is a rich repository of studies showcasing the importance of roots to improve the drought adaptation of several crops. Henry *et al*. (2014) outlines the importance of deep rooting in rice, a crop that usually has very shallow root systems, adding to earlier studies highlighting importance of root hydraulic conductivity (Henry 2013). This paper also highlights the impact of G×E interaction, indicating that root traits such as deeper roots and more roots at depth can indeed improve rice productivity, but not in all environments. Two studies in this issue highlight specific crop cases highlighting the importance of water extraction at depth in wheat (Ober *et al*. 2014) and potatoes (Puértolas *et al*. 2014). A review paper in a companion InterDrought IV special issue introduces new ways to study roots by modelling root architecture and anatomical traits in 3 dimensions (Lynch *et al*. 2014). Two more papers in this special issue use crop modelling to simulate the effect of altering root traits on water productivity (Christopher *et al*. 2014; Kholová *et al*. 2014). We conclude that the scientific community is progressing towards a much more detailed understanding of root system form and function, and anticipate that this will play an important role in improving the drought adaptation of our crops.

In summary, several key topics were debated in InterDrought IV and this special issue reflects the multidisciplinarity of this approach. The last paper in this issue (Turner *et al*. 2014) reflects on the progresses being made in these different research areas, taking stocks of the different presentation at InterDrought IV, highlighting hopes and challenges for the future.

References

Berger JD, Ludwig C (2014) Contrasting adaptive strategies to terminal drought stress gradients in Mediterranean legumes: phenology, productivity, and water relations in wild and domesticated *Lupinus luteus* L. *Journal of Experimental Botany.* doi:10.1093/jxb/eru006

Blum A (2013) The Interdrought Conference in perspective. *Journal of Experimental Botany* **64**(18), 5773–5774. doi:10.1093/jxb/err118

Blum A (2014) Genomics for drought resistance – getting down to earth. *Functional Plant Biology* **41**(10–11), 1191–1198. doi:10.1071/FP14018

Christopher JT, Veyradier M, Borrell AK, Harvey G, Fletcher S, Chenu K (2014) Phenotyping novel stay-green traits to capture genetic variation in senescence dynamics. *Functional Plant Biology* **41**(10–11), 1035–1048. doi:10.1071/FP14052

Fereres E, Orgaz F, Gonzalez-Dugo V, Testi L, Villalobos FJ (2014) Balancing crop yield and water productivity tradeoffs in herbaceous and woody crops. *Functional Plant Biology* **41**(10–11), 1009–1018. doi:10.1071/FP14042

Henry A (2013) IRRI's drought stress research in rice with emphasis on roots: accomplishments over the last 50 years. *Plant Root* **7**, 92–106. doi:10.3117/plantroot.7.92

Henry A, Dixit S, Mandal NP, Anantha MS, Torres R, Kumar A (2014) Grain yield and physiological traits of rice lines with the drought yield QTL $qDTY_{12.1}$ showed different responses to drought and soil characteristics in upland environments. *Functional Plant Biology* **41**(10–11), 1066–1077. doi:10.1071/FP13324

Kapanigowda MH, Payne WA, Rooney WL, Mullet JE, Balota M (2014) Quantitative trait locus mapping of the transpiration ratio related to preflowering drought tolerance in sorghum (*Sorghum bicolor*). *Functional Plant Biology* **41**(10–11), 1049–1065. doi:10.1071/FP13363

Kholová J, McLean G, Vadez V, Craufurd P, Hammer GL (2013) Drought stress characterization of post-rainy season (*rabi*) sorghum in India. *Field Crops Research* **141**, 38–46. doi:10.1016/j.fcr.2012.10.020

Kholová J, Murugesan T, Kaliamoorthy S, Malayee S, Baddam R, Hammer GL, McLean G, Deshpande S, Hash CT, Craufurd PQ, Vadez V (2014) Modelling the effect of plant water use traits on yield and stay-green expression in sorghum. *Functional Plant Biology* **41**(10–11), 1019–1034. doi:10.1071/FP13355

Lynch JP, Chimungu JG, Brown KM (2014) Root anatomical phenes associated with water acquisition from drying soil: targets for crop improvement. *Journal of Experimental Botany* doi:10.1093/jxb/eru162

Ober ES, Werner P, Flatman E, Angus WJ, Jack P, Smith-Reeve L, Tapsell C (2014) Genotypic differences in deep water extraction associated with drought tolerance in wheat. *Functional Plant Biology* **41**(10–11), 1078–1086. doi:10.1071/FP14094

Puértolas J, Ballester C, Elphinstone ED, Dodd IC (2014) Two potato (*Solanum tuberosum*) varieties differ in drought tolerance due to differences in root growth at depth. *Functional Plant Biology* **41** (10–11), 1107–1118. doi:10.1071/FP14105

Sinclair TR, Messina CD, Beatty A, Samples M (2010) Assessment across the United States of the benefits of altered soybean drought traits. *Agronomy Journal* **102**(2), 475–482. doi:10.2134/agronj2009.0195

Thudi M, Gaur PM, Krishnamurthy L, Mir RR, Kudapa H, Fikre A, Kimurto P, Tripathi S, Soren KR, Mulwa R, Bharadwaj C, Datta S, Chaturvedi SK, Varshney RK (2014) Genomics-assisted breeding for drought tolerance in chickpea. *Functional Plant Biology* **41**(10–11), 1178–1190. doi:10.1071/FP13318

Tramontini S, Döring J, Vitali M, Ferrandino A, Stoll M, Lovisolo C (2014) Soil water-holding capacity mediates hydraulic and hormonal signals of near-isohydric and near-anisohydric *Vitis* cultivars in potted grapevines. *Functional Plant Biology* **41**(10–11), 1119–1128. doi:10.1071/FP13263

Turner NC, Blum A, Cakir M, Steduto P, Tuberosa R, Young N (2014) Strategies to increase the yield and yield stability of crops under drought – are we making progress? *Functional Plant Biology* **41** (10–11), 1199–1206. doi:10.1071/FP14057

Vadez V, Soltani A, Sinclair TR (2012) Modelling possible benefits of root related traits to enhance terminal drought adaptation of chickpea. *Field Crops Research* **137**, 108–115. doi:10.1016/j.fcr.2012.07.022

Vadez V, Kholova J, Medina S, Kakkera A, Anderberg H (2014) Transpiration efficiency: new insights into an old story. *Journal of Experimental Botany* doi:10.1093/jxb/eru040