

# Functional Plant Biology

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### Special Issue: InterDrought IV

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

*Vincent Vadez, Jairo Palta and Jens Berger*      v–vi

*Review: Balancing crop yield and water productivity tradeoffs in herbaceous and woody crops*

*Elías Fereres, Francisco Orgaz,  
Victoria Gonzalez-Dugo, Luca Testi  
and Francisco J. Villalobos*

1009–1018

Trade-offs between crop yield and water productivity (WP; yield divided by water use) are important in water-limited situations. Genetic improvement for WP generally has yield trade-offs, whereas management measures devised to improve WP tend to enhance yield as well. In contrast to the behaviour of the major herbaceous crops, WP increases in woody crops in response to water stress, facilitating the application of deficit irrigation strategies.

*Modelling the effect of plant water use traits on yield and stay-green expression in sorghum*

*Jana Kholová, Tharanya Murugesan,  
Sivasakthi Kaliamoorthy, Srikanth Malayee,  
Rekha Baddam, Graeme L. Hammer,  
Greg McLean, Santosh Deshpande,  
C. Thomas Hash, Peter Q. Craufurd  
and Vincent Vadez*

1019–1034

Post-rainy sorghum production, the source of livelihood in developing countries, is being decimated by drought. Water use traits linked to stay-green expression were modelled and are predicted to have positive effect on sorghum production in target groups of environments in India. Trait-based breeding approach could enhance the production in target environments world-wide.

*Phenotyping novel stay-green traits to capture genetic variation in senescence dynamics*

*John T. Christopher, Mathieu Veyradier,  
Andrew K. Borrell, Greg Harvey,  
Susan Fletcher and Karine Chenu*

1035–1048

Stay-green crops retain green leaves longer after anthesis which can improve yield, particularly under water-limitation. We describe a new method to monitor and analyse the dynamics of canopy greenness with improved detection and interpretation of genotypic variation in stay-green. It is anticipated that selection for the identified novel stay-green traits will enhance genetic progress toward high-yielding cultivars.

*Quantitative trait locus mapping of the transpiration ratio related to preflowering drought tolerance in sorghum (*Sorghum bicolor*)*

*Mohankumar H. Kapanigowda, William A. Payne,  
William L. Rooney, John E. Mullet  
and Maria Balota*

1049–1065

Improving the ratio of biomass produced to water transpired is one way to improve water productivity, which is necessary to increase production to feed 9.6 billion by 2050. The study aimed to understand the genetic basis of the transpiration ratio (A:E), and the genetic and physiological determinants of water use in sorghum. Favourable alleles for A:E traits related to preflowering drought tolerance along with stay-green may help develop more drought-tolerant sorghum cultivars.

*Cover illustration: (Left) Aerial picture from a peanut field at the ICRISAT-Sahelian Center in Niger (Jean Louis Ragot, IRD). (Upper right) Staygreen phenotype expression in sorghum under terminal stress at ICRISAT-HQ, Patancheru, India (Vincent Vadez, ICRISAT). (Lower right) Lysimetric facility at ICRISAT-HQ, Patancheru, India (Vincent Vadez, ICRISAT).*

<p>Grain yield and physiological traits of rice lines with the drought yield QTL <i>qDTY<sub>12.1</sub></i> showed different responses to drought and soil characteristics in upland environments</p> <p><b>Amelia Henry, Shalabh Dixit, Nimai P. Mandal, M. S. Anantha, Rolando Torres and Arvind Kumar</b></p>	1066–1077	<p>The major-effect drought-yield quantitative trait locus <i>qDTY<sub>12.1</sub></i> in rice was evaluated across 18 upland experiments. The yield advantage from <i>qDTY<sub>12.1</sub></i> was highest under intermittent drought stress, where yields were greater than 0.5 t ha<sup>-1</sup>, whereas the effects of <i>qDTY<sub>12.1</sub></i> on lateral root and transpiration efficiency were observed under a range of conditions. <i>qDTY<sub>12.1</sub></i> therefore showed different environmental responses for grain yield and physiological traits.</p>
<p>Genotypic differences in deep water extraction associated with drought tolerance in wheat</p> <p><b>Eric S. Ober, Peter Werner, Edward Flatman, William J. Angus, Peter Jack, Lucy Smith-Reeve and Chris Tapsell</b></p>	1078–1086	<p>Accessing sufficient soil moisture is vital to maintaining yield during droughts, but to produce improved varieties for such conditions breeders must be able to identify lines with deep root systems. We found that wheat varieties differed in the ability to mine water from deep soil layers, which was related to drought tolerance and without significant yield penalty. These findings and the methods employed should help validate new candidate lines to realise greater breeding progress for water limited conditions.</p>
<p>Partial root zone drying exerts different physiological responses on field-grown grapevine (<i>Vitis vinifera</i> cv. Monastrell) in comparison to regulated deficit irrigation</p> <p><b>Pascual Romero, Juan Gabriel Pérez-Pérez, Francisco M. del Amor, Adrián Martínez-Cutillas, Ian C. Dodd and Pablo Botía</b></p>	1087–1106	<p>High irrigation volumes applied to the wet part of the root system are critical to successfully implement partial root zone drying irrigation (PRI) to improve vine performance compared to regulated deficit irrigation under semiarid conditions. Physiological responses induced by PRI were due to both the placement of irrigation and the volume of water. Thresholds and optima of soil water content in wet and dry root zones were established.</p>
<p>Two potato (<i>Solanum tuberosum</i>) varieties differ in drought tolerance due to differences in root growth at depth</p> <p><b>Jaime Puértolas, Carlos Ballester, E. David Elphinstone and Ian C. Dodd</b></p>	1107–1118	<p>Since potato crops often require supplemental irrigation, selecting drought-tolerant varieties might help save water. We tested the importance of root biomass growth by comparing the physiology of two varieties with contrasting drought tolerance. When root growth was constrained, there were no genotypic differences in shoot physiological responses as the soil dried. Under field conditions, the drought-tolerant variety had greater root growth and maintained yield with less irrigation by better accessing moist soil layers deeper in the profile.</p>
<p>Soil water-holding capacity mediates hydraulic and hormonal signals of near-isohydric and near-anisohydric <i>Vitis</i> cultivars in potted grapevines</p> <p><b>Sara Tramontini, Johanna Döring, Marco Vitali, Alessandra Ferrandino, Manfred Stoll and Claudio Lovisolo</b></p>	1119–1128	<p>The ecophysiological behaviour of grapevine cultivars in response to drought is influenced by the soil conditions and by the plant genotype. These two components interact through a complex of hydraulic and hormonal signal exchanges occurring between roots and leaves. Our work highlights the differences in these signals observed in a near-isohydric and a near-anisohydric grapevine cultivars on two soil substrates with different textures, causing different dynamics of water deprivation during an imposed increasing water stress.</p>
<p>Mucilage exudation facilitates root water uptake in dry soils</p> <p><b>Mutez A. Ahmed, Eva Kroener, Maire Holz, Mohsen Zarebanadkouki and Andrea Carminati</b></p>	1129–1137	<p>As roots take up water and the soil dries, water depletion is expected to occur near the root surface, ultimately limiting root water uptake. By exuding mucilage, a gel that can hold much water, roots keep the soil in their vicinity wet and can better extract water from dry soils. Mucilage exudation seems to be an optimal plant trait that favours the capture of water during drought.</p>

Harvest index combined with impaired N availability constrains the responsiveness of durum wheat to elevated [CO<sub>2</sub>] concentration and terminal water stress

**Gorka Erice, Alvaro Sanz-S  ez, Amadeo Urdi  in, Jose L. Araus, Juan Jos   Irigoyen, Iker Aranjuelo** 1138–1147

Despite the predicted increase in ambient CO<sub>2</sub> concentration ([CO<sub>2</sub>]), agricultural production is expected to be impacted by stressful conditions. We aimed to characterise the role of harvest index (HI) in durum wheat under elevated [CO<sub>2</sub>] and terminal drought stress. Regardless of water treatment, plants with high HI increased biomass production under elevated [CO<sub>2</sub>], but those with low HI showed photosynthetic acclimation symptoms. Leaf N assimilation, carbohydrate build-up and limitations in CO<sub>2</sub> diffusion were the main parameters involved in responsiveness.

Individual and combined effects of transient drought and heat stress on carbon assimilation and seed filling in chickpea

**Rashmi Awasthi, Neeru Kaushal, Vincent Vadez, Neil C. Turner, Jens Berger, Kadambot H. M. Siddique and Harsh Nayyar** 1148–1167

Droughts are often accompanied by rising temperatures, severely affecting seed filling. The effects of these stresses, individually or combined, on biochemical processes related to seed filling was investigated in chickpea genotypes having contrasting sensitivity to heat and drought stress. Leaf photosynthetic function and sucrose metabolism in seeds were severely disrupted, especially by combined stress, resulting in reductions in seed weight and yield. A drought-tolerant genotype appeared to have partial cross-tolerance to heat stress.

Physiological basis of salt stress tolerance in rice expressing the antiapoptotic gene *SJATP*

**Thi My Linh Hoang, Brett Williams, Harjeet Khanna, James Dale and Sagadevan G. Mundree** 1168–1177

Salinity is a growing problem worldwide that causes a significant reduction in crop yields. We have addressed this problem by manipulating the programmed cell death pathways in rice, resulting in enhanced salt stress tolerance. The implication is that farmers could grow rice containing such a trait in environments where salinisation of the soil exists, thereby addressing food security needs.

Review: Genomics-assisted breeding for drought tolerance in chickpea

**Mahendar Thudi, Pooran M. Gaur, Lakshmanan Krishnamurthy, Reyazul R. Mir, Himabindu Kudapa, Asnake Fikre, Paul Kimurto, Shailesh Tripathi, Khela R. Soren, Richard Mulwa, Chellapilla Bharadwaj, Subhojit Datta, Sushil K. Chaturvedi and Rajeev K. Varshney** 1178–1190

For enhancing precision and efficiency in chickpea breeding especially for drought tolerance, large-scale genomic resources have been developed. These resources together with genetics and physiological approaches facilitated dissecting complex phenomenon of drought tolerance. Marker-assisted backcrossing has generated several lines with enhanced yield under rainfed conditions. Such advances have made it possible to deploy genomics-assisted breeding for drought tolerance in chickpea.

Perspective: Genomics for drought resistance – getting down to earth

**Abraham Blum** 1191–1198

This opinionated review inquires why, after 20 years of extensive research into the genomics of drought resistance, there are hardly any transgenic genetically modified drought-resistant crop cultivar on the market to date. An important reason is that often, the drought stress simulations and testing methods used in genomics are at fault. Guidelines for relevant drought stress physiological methods in genomics are suggested.

Perspective: Strategies to increase the yield and yield stability of crops under drought – are we making progress?

**Neil C. Turner, Abraham Blum, Mehmet Cakir, Pasquale Steduto, Roberto Tuberosa and Neil Young** 1199–1206

Agronomic and genetic progress to improve the drought tolerance of crops for water-limited environments was showcased at the interdisciplinary InterDrought-IV conference held in Perth Australia in September 2013. The integration of breeding, precision phenotyping, genomics and molecular technologies, field evaluation in target environments, and the use of crop growth models has resulted in cultivars with increased yields in drought-prone environments. The paper recommends that further research is required to ensure that progress continues and even increases to meet the nutritional demands of the world's increasing population in the face of climate change.