

Functional Plant Biology

Contents

Volume 44 Issue 1 2017

Special Issue: Plant Phenotyping

Foreword: Plant phenotyping: increasing throughput and precision at multiple scales

Malcolm J. Hawkesford and Argelia Lorence v-vii

Hyperspectral imaging reveals the effect of sugar beet quantitative trait loci on *Cercospora* leaf spot resistance

Marlene Leucker, Mirwaes Wahabzada, Kristian Kersting, Madlaina Peter, Werner Beyer, Ulrike Steiner, Anne-Katrin Mahlein and Erich-Christian Oerke

1–9

As crops are permanently threatened by pests and pathogens, breeding of resistant varieties is an important strategy to control these risks. During the breeding processes, an effective and reliable evaluation of promising candidates is necessary, but often difficult and laborious; therefore, a sensor-based method was used, revealing spatial and temporal differences in *Cercospora* leaf spot resistance of sugar beet lines with closely related genetic backgrounds. The method proved to be highly sensitive to quantitative differences in resistance and may improve resistance breeding.

Micron-scale phenotyping quantification and three-dimensional microstructure reconstruction of vascular bundles within maize stalks based on micro-CT scanning

Jianjun Du, Ying Zhang, Xinyu Guo, Liming Ma, Meng Shao, Xiaodi Pan and Chunjiang Zhao

10–22

Micro-scale phenotyping analysis of vascular bundles is valuable for phenotypic identification of germplasm resources. We developed a sample preparation protocol for micro-CT imaging of corn stalks, and designed an automatic image processing pipeline for phenotyping analysis of vascular bundles. These methods have potential to improve the throughput and quality of micro-scale phenotypic traits, and are expected to be useful in genetic and physiological studies to discover links between stalk anatomy and functions such as water transportation efficiency, mechanical properties.

Observation of plant–pathogen interaction by simultaneous hyperspectral imaging reflection and transmission measurements

Stefan Thomas, Mirwaes Wahabzada, Matheus Thomas Kuska, Uwe Rascher and Anne-Katrin Mahlein

23–34

Phenotyping is the most time consuming step in the process of breeding new plants for increased pathogen resistance: this could be improved through hyperspectral imaging. During experiments with different barley lines under pathogen pressure the novel technique of transmission based spectral imaging measurement was evaluated and compared with reflection based spectral imaging. The results of this study provide basic information about strengths and weaknesses of different hyperspectral measuring methods to be considered in future work

Cover illustration: (Upper left) Overview of the ETH Field Phenotyping Platform (FIP) at ETH plant research station Lindau-Eschikon (WGS84: 47.449 N, 8.682 E) acquired by UAV: D. Constantin, M. Rehak and Y. Akhtman, EPFL ENAC TOPO (see Kirchgessner *et al.* pp. 154–168). Field, poles and winch houses are well visible. Image by Norbert Kirchgessner. (Upper right) The cultivation system of the phenotyping system, *GrowScreen-PaGe* for non-invasive, high throughput phenotyping of root systems (see Gioia *et al.* pp. 76–93). Image by Tania Gioia. (Lower left) Automatic methods to detect and quantify wheat ears in an RGB image (see Virlet *et al.* pp. 143–153). Image by Pouria Sadeghi-Tehran. (Lower right) Infrared thermal images of young sugar beet plants under regular water supply (control), drought stress (17 days) and during rewetting (8 days following 9 days of drought stress) (see Wedeking *et al.* pp. 119–133). The arrow indicates the measured leaf. Image by Anne-Katrin Mahlein.

<p>Phenotyping oilseed rape growth-related traits and their responses to water deficit: the disturbing pot size effect</p> <p>Anaëlle Dambreville, Mélanie Griolet, Gaëlle Rolland, Myriam Dauzat, Alexis Bédiée, Crispulo Balsera, Bertrand Muller, Denis Vile and Christine Granier</p>	35–45	<p>Plant phenotyping platforms allow high-throughput experiments, and facilitate the study of plant growth to precisely monitored watering conditions. This study describes the disturbing effect of pot size on oilseed rape responses to water deficit. Our results raise the awareness of the need to carefully consider the pot size when designing protocols of high-throughput phenotyping experiments.</p>
<p>Use of infrared thermography for monitoring crassulacean acid metabolism</p> <p>Bronwyn J. Barkla and Timothy Rhodes</p>	46–51	<p>Infrared thermography for monitoring changes in leaf temperature as a consequence of reduced transpiration due to daytime stomatal closure in crassulacean acid metabolism (CAM) plants provides a rapid, non-invasive and economically attractive alternative to conventional gas exchange measurements for detecting CAM. Here we demonstrate the use of infrared (IR) thermography in the facultative CAM plant <i>Mesembryanthemum crystallinum</i> and show how it can be used to detect CAM in previously unstudied species.</p>
<p>Pot size matters revisited: does container size affect the response to elevated CO₂ and our ability to detect genotypic variability in this response in wheat?</p> <p>Maryse Bourgault, Andrew T. James and M. Fernanda Dreccer</p>	52–61	<p>The next step in wheat climate change adaptation research is to evaluate responses of individual cultivars to elevated CO₂. This will require the evaluation of large numbers of genotypes, and for practical reasons, preliminary studies are most likely to be conducted in controlled environments with container-grown plants. However, this might create problems or reduce the ability to detecting true cultivar responses.</p>
<p>Review: Approaches to three-dimensional reconstruction of plant shoot topology and geometry</p> <p>Jonathon A. Gibbs, Michael Pound, Andrew P. French, Darren M. Wells, Erik Murchie and Tony Pridmore</p>	62–75	<p>The need for increased crop yields is becoming urgent as the amount of arable land available is reduced and environmental factors worsen, however, plant phenotyping has been identified as a key bottleneck in the process of improving crop yields. Here we review approaches to 3D shoot reconstruction to improve phenotyping using image-based methods. An automated system capable of producing three-dimensional (3D) models of plants would significantly aid phenotyping practice, increase accuracy and repeatability of measurements and potentially aid the process of improved crop yields.</p>
<p>GrowScreen-PaGe, a non-invasive, high-throughput phenotyping system based on germination paper to quantify crop phenotypic diversity and plasticity of root traits under varying nutrient supply</p> <p>Tania Gioia, Anna Galinski, Henning Lenz, Carmen Müller, Jonas Lentz, Kathrin Heinz, Christoph Briese, Alexander Putz, Fabio Fiorani, Michelle Watt, Ulrich Schurr and Kerstin A. Nagel</p>	76–93	<p>Non-invasive root phenotyping is challenging. We introduce <i>GrowScreen-PaGe</i>, a rapid, cost-effective and high-resolution method for non-invasive, high-throughput phenotyping based on flat germination paper for studying root system traits and growth dynamics of crop plants. We demonstrate that this platform can be used to estimate root traits that reliably capture heritable diversity between genotypes and species.</p>
<p>Moderate to severe water limitation differentially affects the phenome and ionome of <i>Arabidopsis</i></p> <p>Lucia M. Acosta-Gamboa, Suxing Liu, Erin Langley, Zachary Campbell, Norma Castro-Guerrero, David Mendoza-Cozatl and Argelia Lorence</p>	94–106	<p>Water limitation is known to affect plant growth and yield. To begin dissecting time-dependent effects of water limitation in <i>Arabidopsis</i>, we combined high-throughput phenomics and ionomics. These two approaches allowed us to quantify the negative effects of water limitation at critical points during plant development.</p>

<p>Review: The advantages of functional phenotyping in pre-field screening for drought-tolerant crops</p> <p>Boaz Negin and Menachem Moshelion</p>	107–118	<p>Breeding for stress tolerant crops is a highly challenging task. In this review we suggest four key components to be considered in pre-field screens (phenotyping) for complex, quantitative, traits under drought conditions. Moreover, we emphasise the advantages in using non-imaging, physiology-based, high-throughput phenotyping systems and diagnostic models as a preferred way to understand and characterise plant response to stress conditions.</p>
<p>Osmotic adjustment of young sugar beets (<i>Beta vulgaris</i>) under progressive drought stress and subsequent rewatering assessed by metabolite analysis and infrared thermography</p> <p>Rita Wedeking, Anne-Katrin Mahlein, Ulrike Steiner, Erich-Christian Oerke, Heiner E. Goldbach and Monika A. Wimmer</p>	119–133	<p>In this study we aimed to better understand the relations between the external phenotype of young sugar beets and corresponding physiological and metabolic processes under drought stress and rewatering, ultimately providing tools to improve phenotypic approaches for drought tolerance. Using physiological, biochemical and a non-destructive phenotyping method, distinct stress phases and differential speed of recovery for selected physiological and metabolic processes were distinguished. Combination of these methods might be used to speed up the selection of drought-adapted cultivars in breeding programs.</p>
<p>Comparative performance of spectral and thermographic properties of plants and physiological traits for phenotyping salinity tolerance of wheat cultivars under simulated field conditions</p> <p>Yuncai Hu, Harald Hackl and Urs Schmidhalter</p>	134–142	<p>Specific physiological traits are considered reliable indicators of salinity tolerance of wheat (<i>Triticum aestivum</i> L.) cultivars. As an alternative, spectral sensing is sufficiently sensitive to differentiate cultivars for differences in salinity tolerance, with considerable potential for high-throughput screening of phenotypic traits associated with this tolerance.</p>
<p>Review: Field Scanalyzer: An automated robotic field phenotyping platform for detailed crop monitoring</p> <p>Nicolas Virlet, Kasra Sabermanesh, Pouria Sadeghi-Tehran and Malcolm J. Hawkesford</p>	143–153	<p>The ability to dissect the genetic control of complex traits is limited by the ability to accurately monitor and measure plant performance. Here, a world first in automated high-throughput field robotic platforms is presented for the continual and detailed monitoring of plant growth. This platform provides detailed descriptions of canopy development across the entire lifecycle of the crop, with a high-degree of accuracy and reproducibility.</p>
<p>The ETH field phenotyping platform FIP: a cable-suspended multi-sensor system</p> <p>Norbert Kirchgessner, Frank Liebisch, Kang Yu, Johannes Pfeifer, Michel Friedli, Andreas Hund and Achim Walter</p>	154–168	<p>Crop phenotyping is a significant bottleneck of research in breeding and precision agriculture, which demands rapid data acquisition in the field. We established a cable-suspended phenotyping platform covering a field of 1 ha. The platform facilitates continuous analysis of several crops with multiple sensors throughout the year and provides reference data for mobile phenotyping platforms such as drones.</p>
<p>Comparison of ground cover estimates from experiment plots in cotton, sorghum and sugarcane based on images and ortho-mosaics captured by UAV</p> <p>Tao Duan, Bangyou Zheng, Wei Guo, Seishi Ninomiya, Yan Guo and Scott C. Chapman</p>	169–183	<p>It is challenging to efficiently and accurately estimate ground cover, which is an important physiological trait affecting crop radiation capture, water-use efficiency and grain yield. Here we compared two methods to estimate plot-level ground cover for three species automatically from UAV captured images. The method is suitable for high throughput phenotyping for applications in agronomy, physiology and breeding for different crop species.</p>