

Functional Plant Biology

Contents

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Special Issue: Plant Phenotyping

Introduction: Phenotyping plants: genes, phenes and machines

Roland Pieruschka and Hendrik Poorter 813–820

This article focuses on the issue of plant phenotyping and the challenge to link it to processes at the molecular level. To bridge the two, non-invasive approaches and evaluation tools are developed, complemented by e-infrastructure for quantitative analysis of structure and function of plants. The article closes by introducing the content of this special issue on Plant Phenotyping.

Review: The art of growing plants for experimental purposes: a practical guide for the plant biologist

Hendrik Poorter, Fabio Fiorani, Mark Stitt, Uli Schurr, Alex Finck, Yves Gibon, Björn Usadel, Rana Munns, Owen K. Atkin, François Tardieu and Thijs L. Pons 821–838

Many experiments with plants are conducted under (semi-) controlled conditions. Here we provide a practical guide to assist researchers to choose an appropriate environmental scenario for their experiments. Moreover, we draw attention to the way different levels of abiotic stress could be applied with improved levels of relevance and provide a basic and more extended checklist to report on experimental conditions.

Review: Pot size matters: a meta-analysis of the effects of rooting volume on plant growth

Hendrik Poorter, Jonas Bühler, Dagmar van Dusschoten, José Climent and Johannes A. Postma 839–850

A meta-analysis of 65 studies on the effect of pot size shows that the usage of small pots retards plant growth and can reduce treatment effects; ~65% of the studies in the plant biology literature are conducted on relatively large plants in small pots, resulting in more than 1 g of total dry biomass per litre of rooting volume. When this ratio of 1 g L⁻¹ is exceeded, pot size is likely to be constraining plant growth.

Phenotyping for drought tolerance in grain crops: when is it useful to breeders?

J. B. Passioura 851–859

Breeding for drought tolerance in grain crops requires different traits with different types of drought. Phenotyping of large numbers of genotypes, both in the field and in controlled environments, is needed to identify novel traits that can be effectively incorporated into breeding programs. Appropriate combinations of such traits will lift the yield of crops towards their water-limited potential in different environments.

Cover illustration: (from left to right) 1. NMR image of a *Beta vulgaris* plant grown for 48 days in a pot with a volume of 1.3 L. Roots in the inner 50% of the soil volume (furthest away from wall and bottom) are colour-coded yellow, roots in the outer 50% blue. The developing storage root is colour-coded red (Poorter *et al.* pp. 839–850). 2. A *Beta vulgaris* beet analysed with MRI–PET. The colour code indicates transport of C11 marked assimilates to the roots (for details see Jahnke *et al.* 2009, *Plant Journal* **59**, 634–644). 3. Colour-coded images with main roots (in green) and lateral roots (in red) of an *Arabidopsis thaliana* (Nagel *et al.* pp. 891–904). 4. NMR image of a *Hordeum vulgare* plant grown for 44 days in a pot with a volume of 1.3 L. Roots in the inner 50% of the soil volume (furthest away from wall and bottom) are colour-coded yellow, roots in the outer 50% blue. The stem part that was masked from the analysis is shown in red (Poorter *et al.* pp. 839–850).

Measuring the diurnal pattern of leaf hyponasty and growth in *Arabidopsis* – a novel phenotyping approach using laser scanning
Tino Dornbusch, Séverine Lorrain, Dmitry Kuznetsov, Arnaud Fortier, Robin Liechti, Ioannis Xenarios and Christian Fankhauser 860–869

Increased leaf elevation angle (hyponasty) and leaf elongation in *Arabidopsis* are caused by different environmental stimuli such as shading by surrounding vegetation. Here we report on a phenotyping approach based on laser scanning to measure the diurnal pattern of these two growth responses. High-throughput monitoring of individual plants can be achieved non-invasively during several days under different light conditions with high temporal resolution.

SPICY: towards automated phenotyping of large pepper plants in the greenhouse
Gerie van der Heijden, Yu Song, Graham Horgan, Gerrit Polder, Anja Dieleman, Marco Bink, Alain Palloix, Fred van Eeuwijk and Chris Glasbey 870–877

A new image analysis method is developed to facilitate the breeding of better varieties. Using 8 cameras, a 3D picture of a plant is reconstructed which is used to automatically measure features of greenhouse plants, correlating well with manual measurements. This method can automate phenotyping of plants, which is considered a major bottleneck in the progress of plant breeding.

Early drought stress detection in cereals: simplex volume maximisation for hyperspectral image analysis
Christoph Römer, Mirwaes Wahabzada, Agim Ballvora, Francisco Pinto, Micol Rossini, Cinzia Panigada, Jan Behmann, Jens Léon, Christian Thurau, Christian Bauckhage, Kristian Kersting, Uwe Rascher and Lutz Plümer 878–890

Interpretable classification methods optimised for massive datasets are a prerequisite for phenotyping with hyperspectral imaging sensors. The proposed technique, simplex volume maximisation, is optimised for these conditions and was able to detect drought stress faster than established vegetation indices. This method has the potential to lead to intuitive data exploration and easier visualisation of temporal and spatial stress dynamics.

GROWSCREEN-Rhizo is a novel phenotyping robot enabling simultaneous measurements of root and shoot growth for plants grown in soil-filled rhizotrons
Kerstin A. Nagel, Alexander Putz, Frank Gilmer, Kathrin Heinz, Andreas Fischbach, Johannes Pfeifer, Marc Faget, Stephan Blossfeld, Michaela Ernst, Chryssa Dimaki, Bernd Kastenholz, Ann-Katrin Kleinert, Anna Galinski, Hanno Scharr, Fabio Fiorani and Ulrich Schurr 891–904

Quantitative root phenotyping in soil is challenging. We introduce a new automated phenotyping system (GROWSCREEN-Rhizo) for imaging simultaneously roots and shoots in 2D for plants grown in soil-filled rhizotrons. To validate this method, we studied a diverse set of monocots and dicots species to compare manually scored and imaging derived parameters. We found that the portion of the root system captured during imaging time-series can be used to estimate whole-root parameters.

GlyPh: a low-cost platform for phenotyping plant growth and water use
Gustavo A. Pereyra-Irujo, Emmanuel D. Gasco, Laura S. Peirone and Luis A. N. Aguirrezábal 905–913

Drought is a major limitation to crop yields worldwide. Devices able to automatically simulate droughts and measure plant responses in order to identify tolerant varieties are currently expensive. We have developed a platform that was able to detect differences in drought tolerance among soybean varieties, which is simpler and has a lower construction cost than previously existing devices, thus, being suitable for low-budget researchers, companies and for use in the developing world.

A semi-automatic system for high throughput phenotyping wheat cultivars in-field conditions: description and first results
Alexis Comar, Philippe Burger, Benoit de Solan, Frédéric Baret, Fabrice Daumard and Jean-François Hanocq 914–924

This study presents a semi-automatic system designed to monitor micro-plots of wheat cultivars in field conditions. The measurements are interpreted for crop architecture and biochemical content characterisation and their frequency allows a good description of their dynamics along the growth cycle. This work demonstrates the ability of this system to acquire high throughput phenotyping pertinent data for wheat cultivar characterisation.

A role for root morphology and related candidate genes in P acquisition efficiency in maize
Sylvia Morais de Sousa, Randy T. Clark, Flávia Ferreira Mendes, Antonio Carlos de Oliveira, Maria José Vilaça de Vasconcelos, Sidney Netto Parentoni, Leon V. Kochian, Cláudia Teixeira Guimarães and Jurandir Vieira Magalhães

925–935

One important challenge towards the development of sustainable agricultural systems is the development of cultivars that show high yield associated with an efficient use of natural resources. This is particularly important for phosphorus in view of the limited availability of its reserves. This work investigated the relationship between genes related to root morphology and yield performance under low P conditions, seeking to elucidate the molecular and physiological basis of maize P efficiency with a focus on root morphology traits. Our results should be conducive for establishing early selection strategies for P efficiency in maize, which should eventually help plant breeders to generate cultivars with improved performance under low P conditions.

Phenotyping of wheat cultivars for heat tolerance using chlorophyll *a* fluorescence
Dew Kumari Sharma, Sven Bode Andersen, Carl-Otto Ottosen and Eva Rosenqvist

936–947

A chlorophyll fluorescence protocol was standardised and used for mass screening of 1274 wheat cultivars under heat stress. The screening was repeated three times with increasing selection pressure to identify the contrasting set of cultivars with increased genetic determination of the genotype variation. Chlorophyll fluorescence parameters were evaluated for their ability to detect genetic differences between wheat cultivars. The results are important for further studies to understand the genetic nature of heat stress tolerance.

Data management pipeline for plant phenotyping in a multisite project
Kenny Billiau, Heike Sprenger, Christian Schudoma, Dirk Walther and Karin I. Köhl

948–957

In plant breeding, standardized collection and storage of phenotypic data allow rapid data evaluation and statistical analysis. For a multisite-project, we developed a data warehouse that allows data exchange and storage independent of organizational barriers safeguarding data integrity and intellectual property rights. By outlining the concept and making the software available, we aim to support related phenotyping projects.
