On the Cover: The cover image, entitled “The shape of roots to come,” was composed by Alexander Bucksch from the computed binary image masks of cowpea roots. The image conveys the diversity of root shapes of an emerging crop and the increasingly important algorithmic advances enabled by computational plant sciences. As described in Bucksch et al. (pp. 470–486), computational analysis of root systems excavated and imaged in field conditions enabled the phenotypic differentiation of 188 cowpea genotypes.

FOCUS ON ROOTS

EDITORIAL

Focus on Roots. Niko Geldner and David E. Salt

BREAKTHROUGH TECHNOLOGIES


Testing tomato gene expression with tagged nuclei and ribosomes and CRISPR/Cas9 genome editing shows conservation of SHORT-ROOT gene function.


Automatic methods developed or reproducible field-based phenotyping allow distinction of genotypes, including 13 newly accessible plant root traits.


Neutron radiography traces the transport of deuterated water in soil and roots to reconstruct the water flow across the root tissue and along the xylem.

UPDATES

Plant Nutrition: Root Transporters on the Move. Enric Zelazny and Grégory Vert

The dynamics of nutrient transporters and channels emerges as a critical and highly regulated cellular process controlling nutrient uptake and distribution in plant roots.

Root Nutrient Foraging. Ricardo F.H. Giehl and Nicolaus von Wirén

Root morphological traits that are relevant for nutrient acquisition are regulated by nutrients and the plant’s nutritional status.

Natural Variation of Root Traits: From Development to Nutrient Uptake. Daniela Ristova and Wolfgang Busch

Natural variation of root growth informs on processes that govern root development, responses to nutrient availability, and ion uptake and homeostasis.
Radial Transport of Nutrients: The Plant Root as a Polarized Epithelium.  

Marie Barberon and Niko Geldner

Different routes underlie radial transport of nutrients in plant roots and are influenced by the endodermis permeability and the polarity of transporters.

Branching Out in Roots: Uncovering Form, Function, and Regulation.  

Jonathan A. Atkinson, Amanda Rasmussen, Richard Traini, Ute Voß, Craig Sturrock, Sacha J. Mooney, Darren M. Wells, and Malcolm J. Bennett

The diversity of postembryonic root forms and their functions add to our understanding of the genes, signals and mechanisms regulating lateral and adventitious root branching in the plant models Arabidopsis and rice.

Beyond the Barrier: Communication in the Root through the Endodermis.  

Neil E. Robbins II, Charlotte Trontin, Lina Duan, and José R. Dinneny

The endodermis acts as a barrier to solute and water movement but also has important functions in signaling and morphogenesis.

Strigolactone Involvement in Root Development, Response to Abiotic Stress, and Interactions with the Biotic Soil Environment.  

Yoram Kapulnik and Hinanit Koltai

Strigolactones play a role in root development, root response to nutrient deficiency, and plant interactions in the rhizosphere.

The Origin and Early Evolution of Roots.  

Paul Kenrick and Christine Strullu-Derrien

Exceptionally well-preserved fossils shed light on the earliest roots and their interactions with the environment.

[C] Functional Soil Microbiome: Belowground Solutions to an Aboveground Problem.  

Venkatachalam Lakshmanan, Gopinath Selvaraj, and Harsh P. Bais

The functional soil microbiome is an important parameter in developing a sustainable and effective strategy to increase crop yield and food security.


Clelia De-la-Peña and Víctor M. Loyola-Vargas

Roots and microbes secrete organic compounds into the rhizosphere that influence plant productivity.

[C] Perennial Roots to Immortality.  

Sergi Munné-Bosch

Roots play a key role in determining long life in perennials.

RESEARCH ARTICLES

Low Crown Root Number Enhances Nitrogen Acquisition from Low-Nitrogen Soils in Maize.  

Patompong Saengwilai, Xiaoli Tian, and Jonathan Paul Lynch

Low crown root number improves nitrogen acquisition in maize by enhancing deep soil exploration in low-nitrogen soils.

The optimal lateral root branching density in the maize root system depends on the relative availability of nitrate (a mobile soil resource) and phosphorus (an immobile soil resource), with the optimum shifting to more branches when the nitrate-to-phosphorus ratio is high.

Origin and Development of the Root Cap in Rice. Likai Wang, Huangwei Chu, Zhiyong Li, Juan Wang, Jintao Li, Yang Qiao, Yanru Fu, Tongmin Mou, Chunli Chen, and Jian Xu

Cellular and molecular events are inherent to the formation and development of the root cap in rice.

The anthocyanin reduced Tomato Mutant Demonstrates the Role of Flavonols in Tomato Lateral Root and Root Hair Development. Gregory S. Maloney, Kathleen T. DiNapoli, and Gloria K. Muday

Flavonols contribute to lateral root development through the regulation of auxin transport and root hair and they modulate the levels of reactive oxygen species.

The ASH1-RELATED3 SET-Domain Protein Controls Cell Division Competence of the Meristem and the Quiescent Center of the Arabidopsis Primary Root. Robert Kumpf, Tage Thorstensen, Mohummad Aminur Rahman, Jeffri Heyman, H. Zeynep Nenseth, Tim Lammens, Ulrich Herrmann, Ranjan Swarup, Silje Vete Vei sel, Gitika Emberland, Malcolm J. Bennett, Lieven De Veylder, and Reidunn B. Aalen

A histone Lys methyltransferase gene is expressed in the root stem cell niche and contributes to coordinated divisions in the immediate cell lineage originating from the same stem cell.

Abscisic Acid and LATERAL ROOT ORGAN DEFECTIVE/NUMEROUS INFECTIONS AND POLYPHENOLICS Modulate Root Elongation via Reactive Oxygen Species in Medicago truncatula. Chang Zhang, Amanda Bousquet, and Jeanne M. Harris

Both abscisic acid and a nitrate transporter regulate the production of ROS and the expression of superoxide-generating NADPH oxidase enzymes to regulate root elongation.


Sorghum homologs of a rice gene contributing to P-starvation tolerance enhance P uptake and crop performance in low-P soils via modulation of root system morphology and architecture.


Pi deprivation shifts the subcellular distribution of two key brassinosteroid-related transcriptional effectors to trigger shallower root system architecture.
Abundant root cortical aerenchyma improves plant growth under nitrogen-limiting conditions by decreasing root metabolic costs, enhancing soil exploration in deep soil strata, thereby increasing nitrogen acquisition at greater depths.

Extended branching order classification describes morphological variability in root systems and respiration better than traditional root diameter classes or root orders alone.

Glycosylphosphatidylinositol-anchor biosynthesis and glycosylphosphatidylinositol modification of proteins are central to coordinated plant development.

Root exudation of nicotianamine is required for excess zinc tolerance.

An enzyme of cytosolic hexose phosphate metabolism is essential for plant reproduction and important for photosynthesis.

Ginkobilobin2 is shown to exert antifungal activity through its interaction with α1,2-linked mannose chains of fungal cell-wall mannan, which provides clues to the molecular function of the DUF26 protein family.

Plants expressing two sesquiterpene synthases emitted increased quantities of target volatiles without changes to other volatiles, defense, growth, or yield in transformants or neighboring plants.
Unraveling the Mechanism Underlying the Glycosylation and Methylation of Anthocyanins in Peach.  
Jun Cheng, Guochao Wei, Hui Zhou, Chao Gu, Sornkanok Vimolmangkang, Liao Liao, and Yuepeng Han

Diversification of anthocyanins in peach is attributed to glycosylation and methylation.

CELL BIOLOGY

Laccases Direct Lignification in the Discrete Secondary Cell Wall Domains of Protoxylem.  
Mathias Schuetz, Anika Benske, Rebecca A. Smith, Yoichiro Watanabe, Yuki Tobimatsu, John Ralph, Taku Demura, Brian Ellis, and A. Lacey Samuels

The discrete localization of laccases to secondary cell walls directs lignification in protoxylem.

FRIENDLY Regulates Mitochondrial Distribution, Fusion, and Quality Control in Arabidopsis.  
Amr M. El Zawily, Markus Schwarzländer, Iris Finkemeier, Iain G. Johnston, Abdelilah Benamar, Yongguo Cao, Clémence Gissot, Andreas J. Meyer, Ken Wilson, Raju Datla, David Macherel, Nick S. Jones, and David C. Logan

Disruption of intermitochondrial association affects mitochondrial quality control, leading to mitochondrial stress, cell death, and strong growth defects.

ECOPHYSIOLOGY AND SUSTAINABILITY

Leaf Vein Length per Unit Area Is Not Intrinsically Dependent on Image Magnification: Avoiding Measurement Artifacts for Accuracy and Precision.  
Lawren Sack, Marissa Caringella, Christine Scoffoni, Chase Mason, Michael Rawls, Lars Markesteijn, and Lourens Poorter

Measurements of leaf vein length per area do not increase systematically with image magnification, contrary to a recent claim, given appropriate attention toward accuracy and precision.

Root-Secreted Nicotianamine from Arabidopsis halleri Facilitates Zinc Hypertolerance by Regulating Zinc Bioavailability.  
Munkhtsetseg Tsednee, Shun-Chung Yang, Der-Chuen Lee, and Kuo-Chen Yeh

Root secretion of nicotianamine from zinc-hyperaccumulating Arabidopsis halleri facilitates zinc hypertolerance through coordinating zinc uptake and iron homeostasis in roots.

Increased Ratio of Electron Transport to Net Assimilation Rate Supports Elevated Isoprenoid Emission Rate in Eucalypts under Drought.  
Kaidala Ganesha Srikanta Dani, Ian McLeod Jamie, Iain Colin Prentice, and Brian James Atwell

Volatile isoprenoids emitted by plants, enhanced by photosynthesis under drought, have a significant influence on ozone pollution and global climate.
Analysis of 61 RNA-seq samples reveals the existence of common, rare, and nondetectable transcripts, including ubiquitous transcripts, dominant/subordinate transcripts, and switch transcripts, in terms of their expression and transcript ratio.

An ATP-dependent binding cassette transporter contributes to plant resistance to infection by Pseudomonas syringae and tolerance of abscisic acid.

A plant-specific protein controls the complexity and connectivity of veins in cotyledons.

A proposed regulatory loop segment of the DEK1 transmembrane domain is required for gametophore patterning in Physcomitrella patens.

Tomato fruit chromoplasts exhibit a respiratory process linked to ATP synthesis that uses NAD(P)H as electron donors and represents 25% of total ripe fruit respiration.

Cadmium inhibits controlled nitrate uptake by roots, but this has the beneficial effect of reducing cadmium entry into roots.

A high-affinity rice potassium transporter plays a major role in K acquisition by roots faced with low external K and in K upward transport from roots to shoots in K-deficient rice plants.
Voltage-Sensor Transitions of the Inward-Rectifying K+ Channel KAT1 Indicate a Latching Mechanism Biased by Hydration within the Voltage Sensor.  

Cécile Lefoulon, Rucha Karnik,  

Annegret Honsbein, Paul Vijay Gutla, Christopher Grefen, Janin Riedelsberger, Tomás Poblete, Ingo Dreyer,  

Wendy Gonzalez, and Michael R. Blatt

Manipulating the electrostatic charge network that stabilizes the voltage sensor of the KAT1 K+ channel displaces channel gating across more than 140 mV within the physiological voltage range.

Dynamics of Carbon-Concentrating Mechanism Induction and Protein Relocalization during the Dark-to-Light Transition in Synchronized Chlamydomonas reinhardtii. 

Madeline C. Mitchell,  

Moritz T. Meyer, and Howard Griffiths

In synchronized Chlamydomonas reinhardtii cells, the carbon-concentrating mechanism is induced prior to dawn, which coincides with the relocalization of key proteins to the chloroplast pyrenoid.

Distinct Signaling Mechanisms in Multiple Developmental Pathways by the SCRAMBLED Receptor of Arabidopsis. 

Su-Hwan Kwak, Sooah Woo, Myeong Min Lee,  

and John Schiefelbein

A single receptor-like kinase exhibits distinct signaling requirements to mediate different developmental events in Arabidopsis.

Distinct Roles for Mitogen-Activated Protein Kinase Signaling and CALMODULIN-BINDING TRANSCRIPTIONAL ACTIVATOR3 in Regulating the Peak Time and Amplitude of the Plant General Stress Response. 

Marta Bjornson, Geoffrey Benn, Xingshu Song, Luca Comai,  

Annaliise K. Franz, Abhaya M. Dandekar, Georgia Drakakaki, and Katayoon Dehesh

Unbiased screening through forward and chemical genetics unveils components distinctly regulating the peak time and amplitude of the plant general stress responses.

Oxidative Stress Contributes to Autophagy Induction in Response to Endoplasmic Reticulum Stress in Chlamydomonas reinhardtii. 

Marta Pérez-Martín, María Esther Pérez-Pérez,  

Stéphane D. Lemaire, and José L. Crespo

Alteration of the intracellular redox state during endoplasmic reticulum stress contributes to autophagy activation in Chlamydomonas reinhardtii.

Arabidopsis Triphosphate Tunnel Metalloenzyme2 Is a Negative Regulator of the Salicylic Acid-Mediated Feedback Amplification Loop for Defense Responses. 

Huoi Ung, Wolfgang Moeder,  

and Keiko Yoshioka

A triphosphate tunnel metalloenzyme is a negative regulator in amplification of SA-dependent defense responses.

Large-Scale Identification of Gibberellin-Related Transcription Factors Defines Group VII ETHYLENE RESPONSE FACTORS as Functional DELLA Partners. 

Nora Marín-de la Rosa,  

Berta Sotillo, Pal Miskolczi, Daniel J. Gibbs, Jorge Vicente, Pilar Carbonero, Luis Oñate-Sánchez,  

Michael J. Holdsworth, Rishikesh Bhulerao, David Alabadi, and Miguel A. Blázquez

Transcription factors of the APETALA2 superfamily are regulated by DELLAs which represents a cross regulatory node for gibberellins and ethylene to control apical hook opening.

Continued on next page
A quantitative proteomic approach enables unambiguous protein localization to the plant Golgi apparatus and rank ordering of the Golgi resident proteins by abundance, providing a unique view on the organization of this organelle.

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