

On the Cover: Increasing phosphate uptake by plant roots as well as its transport to the shoot are critical for maximising plant growth with less fertiliser input. At the molecular level, these processes are controlled by a number of negative regulators, including the E2 ubiquitin conjugase PHO2 (PHOSPHATE2) and inhibitors of MYB transcription factor PHR1 (PHOSPHATE STARVATION RESPONSE1) such as SPX1 (SPX DOMAIN GENE 1) and SPX2. These regulators act not only on phosphate transport, but also on plant development and general stress acclimation. Their removal dramatically increases shoot accumulation of phosphate, but knock-out plants often grow poorly or are more sensitive to abiotic stress. In the July issue 174(3), Linn et al. (pp. 1969–1989) used a bioinformatics approach to identify root-cell enriched genes that are either induced by low phosphate stress or that are predicted to interact with a PSI (phosphate-starvation induced) gene product in a root-cell specific manner. The final selection of eleven candidate genes revealed that an unknown WD40 repeat-containing protein, WDD1 (WD40-DOMAIN1), and the abiotic stress responsive calcium sensor CBL1 (CALCINEURIN B-LIKE PROTEIN1) are strong negative regulators of the phosphate starvation response. The image shows that knock-out of either *CBL1* or *WDD1* not only resulted in moderate accumulation of phosphate in shoots, but also significantly improved root and shoot growth in P-limited seedlings (represented by radar plots and root images). Knock-out mutants for both genes showed mis-regulation of PHR1-dependent PSI genes (represented by heat map). *WDD1* is co-expressed with its predicted interactor PHT1;2 (PHOSPHATE TRANSPORTER1;2) in the root epidermis and endodermis, while *CBL1* is expressed in all root cell types with strong expression in the root vasculature (shown here) with increased expression in P-limited roots. Image by Oliver Berkowitz.

ON THE INSIDE

Peter V. Minorsky

1

LETTER TO THE EDITOR

Circadian Regulation and Diurnal Variation in Gas Exchange.

Víctor Resco de Dios

3

COMMENTARY

A Major Advance in Plastid Transformation. Julian M. Hibberd

5

UPDATE

^[OPEN]Plant Glandular Trichomes: Natural Cell Factories of High Biotechnological Interest. Alexandre Huchelmann, Marc Boutry, and Charles Hachez

Glandular trichomes: from developmental aspects to metabolic engineering approaches.

6

RESEARCH ARTICLES

BREAKTHROUGH TECHNOLOGIES

Multiplexed Gene Editing and Protein Overexpression Using a Tobacco mosaic virus Viral Vector. Will B. Cody, Herman B. Scholthof, and T. Erik Mirkov

A new plant virus-based method enables gene knockout screening and plant genetic engineering using transient expression methods.

23

Continued on next page

BIOCHEMISTRY AND METABOLISM

[OPEN] Characterization of Trichome-Expressed BAHD Acyltransferases in *Petunia axillaris* Reveals Distinct Acylsugar Assembly Mechanisms within the Solanaceae. Satya Swathi Nadakuduti, Joseph B. Uebler, Xiaoxiao Liu, A. Daniel Jones, and Cornelius S. Barry

The assembly of plant defense-related acylsugars in Petunia axillaris trichomes requires four acyltransferase activities that are distinct from those catalyzing acylsugar biosynthesis in tomato. 36

[OPEN] 3-Hydroxyisobutyrate Dehydrogenase Is Involved in Both, Valine and Isoleucine Degradation in *Arabidopsis thaliana*. Peter Schertl, Lennart Danne, and Hans-Peter Braun

3-Hydroxyisobutyrate dehydrogenase, an enzyme of the branched-chain amino acid breakdown pathway, is involved in valine and isoleucine but not in leucine degradation in Arabidopsis. 51

Autophagy Deficiency Compromises Alternative Pathways of Respiration following Energy Deprivation in *Arabidopsis thaliana*. Jessica A.S. Barros, João Henrique F. Cavalcanti, David B. Medeiros, Adriano Nunes-Nesi, Tamar Avin-Wittenberg, Alisdair R. Fernie, and Wagner L. Araújo

During carbon starvation, autophagy is associated with protein degradation and impact energy status by regulating alternative respiration via the ETF/ETFQO through a yet unclear mechanism. 62

[OPEN] Manipulation of a Senescence-Associated Gene Improves Fleshy Fruit Yield. Bruno S. Lira, Giovanna Gramegna, Bruna A. Trench, Frederico R. R. Alves, Eder M. Silva, Geraldo F. F. Silva, Venkatesh P. Thirumalaikumar, Alessandra C. D. Lupi, Diego Demarco, Eduardo Purgatto, Fabio T. S. Nogueira, Salma Balazadeh, Luciano Freschi, and Magdalena Rossi

Senescence-associated gene knockdown increases carbon exportation toward sink organs, increasing plant yield in Solanum lycopersicum. 77

[OPEN] Biosynthesis of Diterpenoids in *Tripterygium* Adventitious Root Cultures. Fainmarinat S. Inabuy, Justin T. Fishedick, Iris Lange, Michael Hartmann, Narayanan Srividya, Amber N. Parrish, Meimei Xu, Reuben J. Peters, and B. Markus Lange

Adventitious root cultures provide insights to elucidating the biosynthesis of pharmaceutically relevant diterpenoids in the model genus Tripterygium. 92

A Dynamic Hydro-Mechanical and Biochemical Model of Stomatal Conductance for C_4 Photosynthesis. Chandra Bellasio, Joe Quirk, Thomas N. Buckley, and David J. Beerling

A mechanistic dynamic model predicts CO_2 uptake, water release by C_4 leaves, simulated stomatal responses and water use optimality in response to light fluctuations over 1 day. 104

A Dioxygenase Catalyzes Steroid 16α -Hydroxylation in Steroidal Glycoalkaloid Biosynthesis. Masaru Nakayasu, Naoyuki Umemoto, Kiyoshi Ohyama, Yoshinori Fujimoto, Hyoung Jae Lee, Bunta Watanabe, Toshiya Muranaka, Kazuki Saito, Yukihiko Sugimoto, and Masaharu Mizutani

The 2-oxoglutarate-dependent dioxygenase 16DOX catalyzes steroid 16α -hydroxylation in the steroidal glycoalkaloid (SGA) pathway and is a suitable target for controlling toxic SGA levels in potato. 120

Continued on next page

[CC-BY] Overexpression of the RieskeFeS Protein Increases Electron Transport Rates and Biomass Yield. Andrew J. Simkin, Lorna McAusland, Tracy Lawson, and Christine A. Raines

Overexpression of the Rieske FeS protein results in significant increases in the quantum efficiencies of PSI and PSII, increases in A_{max} , and has the potential to increase crop productivity. 134

[OPEN] Synthesis and Self-Assembly of Cellulose Microfibrils from Reconstituted Cellulose Synthase. Sung Hyun Cho, Pallinti Purushotham, Chao Fang, Cassandra Maranas, Sara M. Díaz-Moreno, Vincent Bulone, Jochen Zimmer, Manish Kumar, and B. Tracy Nixon

Liposome-reconstituted, heterologously expressed cellulose synthases contribute to primary/secondary plant cell walls synthesized the glucan chains that assembled into cellulose microfibrils. 146

CELL BIOLOGY

[OPEN] RopGEF1 Plays a Critical Role in Polar Auxin Transport in Early Development. Yuting Liu, Qingkun Dong, Daniel Kita, Jia-bao Huang, Guolan Liu, Xiaowei Wu, Xiaoyue Zhu, Alice Y. Cheung, Hen-Ming Wu, and Li-zhen Tao

The Arabidopsis RopGEF1 is important for the localization of auxin influx carrier AUX1 and accumulation of efflux carrier PIN proteins, thereby affecting auxin-dependent growth and development. 157

[OPEN] MILDEW RESISTANCE LOCUS O Function in Pollen Tube Reception Is Linked to Its Oligomerization and Subcellular Distribution. Daniel S. Jones, Jing Yuan, Benjamin E. Smith, Andrew C. Willoughby, Emily L. Kumimoto, and Sharon A. Kessler

MLOs can substitute for NORTIA function in pollen tube reception if they localize to a Golgi compartment prior to pollen tube arrival and retain the ability to homo-oligomerize. 172

[OPEN] Efficient Plastid Transformation in Arabidopsis. Qiguo Yu, Kerry Ann Lutz, and Pal Maliga

100-fold increased plastid transformation frequency is achieved in ACC2-defective Arabidopsis. 186

[OPEN] SCYL2 Genes Are Involved in Clathrin-Mediated Vesicle Trafficking and Essential for Plant Growth. Ji-Yul Jung, Dong Wook Lee, Stephen Beungtae Ryu, Inhwan Hwang, and Daniel P. Schachtman

Vesicle membrane-associated SCYL2 proteins are vital for plant development. 194

[OPEN] Functional Specialization of Cellulose Synthase Isoforms in a Moss Shows Parallels with Seed Plants. Joanna H. Norris, Xingxing Li, Shixin Huang, Allison M. L. Van de Meene, Mai L. Tran, Erin Killeavy, Arielle M. Chaves, Bailey Mallon, Danielle Mercure, Hwei-Ting Tan, Rachel A. Burton, Monika S. Doblin, Seong H. Kim, and Alison W. Roberts

Regulatory uncoupling of primary and secondary cellulose synthases occurred independently in mosses and seed plants and is associated with convergent evolution of secondary wall structure. 210

ECOPHYSIOLOGY AND SUSTAINABILITY

^[OPEN]Dead or Alive? Using Membrane Failure and Chlorophyll *a* Fluorescence to Predict Plant Mortality from Drought. Carmela R. Guadagno, Brent E. Ewers, Heather N. Speckman, Timothy Llewellyn Aston, Bridger J. Huhn, Stanley B. DeVore, Joshua T. Ladwig, Rachel N. Strawn, and Cynthia Weinig

Chlorophyll fluorescence and cellular leakage from disrupted membranes are reliable indicators of the precise timing of plant mortality from drought and beetle kill across species. 223

^[OPEN]Improving Plant Nitrogen Use Efficiency through Alteration of Amino Acid Transport Processes. Molly Perchlik and Mechthild Tegeder

Pea plants with altered amino acid transport processes produce higher seed yields and use nitrogen (N) more efficiently than wild-type plants in N-poor and N-rich soils. 235

^[OPEN]Leaf Photosynthetic Parameters Related to Biomass Accumulation in a Global Rice Diversity Survey. Mingnan Qu, Guangyong Zheng, Saber Hamdani, Jemaa Essemine, Qingfeng Song, Hongru Wang, Chengcai Chu, Xavier Sirault, and Xin-Guang Zhu

A large-scale survey of photosynthetic parameters and biomass accumulation in a global rice diversity panel reveals critical leaf photosynthetic parameters controlling biomass accumulation. 248

^[OPEN]Redox Control of Aphid Resistance through Altered Cell Wall Composition and Nutritional Quality. Brwa Rasool, Jack McGowan, Daria Pastok, Sue E. Marcus, Jenny A. Morris, Susan R. Verrall, Peter E. Hedley, Robert D. Hancock, and Christine H. Foyer

Low ascorbate oxidase activities lead to a more reduced apoplastic redox state and enhance aphid resistance through changes in cell wall composition and decreased leaf nutritional quality. 259

^[OPEN]Higher Novel L-Cys Degradation Activity Results in Lower Organic-S and Biomass in *Sarcocornia* than the Related Saltwort, *Salicornia*. Assylay Kurmanbayeva, Aizat Bekturova, Sudhakar Srivastava, Aigerim Soltabayeva, Armine Asatryan, Yvonne Ventura, Mohammad Suhail Khan, Octavio Salazar, Nina Fedoroff, and Moshe Sagi

*The low level of organic S in *Sarcocornia* as compared to *Salicornia* is the result of a higher L-cysteine degradation rate by O-acetylserine-(thiol) lyases, especially when supplemented with sulfate.* 272

^[OPEN]Photosynthetic Efficiency as Bioindicator of Environmental Pressure in *A. halleri*. Krzysztof Sitko, Szymon Rusinowski, Hazem M. Kalaji, Michał Szopiński, and Eugeniusz Małkowski

*Environmental parameters and the contamination of soil with heavy metals can have a negative impact on the efficiency of the photosynthetic apparatus of the model Cd/Zn hyperaccumulator *A. halleri*.* 290

GENES, DEVELOPMENT, AND EVOLUTION

^[OPEN]Tissue-Specific Control of the Endocycle by the Anaphase Promoting Complex/Cyclosome Inhibitors UVI4 and DEL1. Jefri Heyman, Stefanie Polyn, Thomas Eekhout, and Lieven De Veylder

Phenotypic characterization of Anaphase Promoting Complex/Cyclosome Inhibitors reveals tissue-dependent roles for the APC/C^{CCS52A1} and APC/C^{CCS52A2} complexes. 303

Continued on next page

[OPEN] Gene Regulatory Networks for the Haploid-to-Diploid Transition of *Chlamydomonas reinhardtii*. Sunjoo Joo, Yoshiki Nishimura, Evan Cronmiller, Ran Ha Hong, Thamali Kariyawasam, Ming Hsiu Wang, Nai Chun Shao, Saif-El-Din El Akkad, Takamasa Suzuki, Tetsuya Higashiyama, Eonseon Jin, and Jae-Hyeok Lee

The zygotic wall program is executed by the heterodimeric homeobox transcription factors GSM1/GSP1 via transcriptional activation and post-transcriptional suppression in Chlamydomonas.

314

[CC-BY] Transcription Factor MYB26 Is Key to Spatial Specificity in Anther Secondary Thickening Formation. Caiyun Yang, Jie Song, Alison C. Ferguson, Doris Klisch, Kim Simpson, Rui Mo, Benjamin Taylor, Nobutaka Mitsuda, and Zoe A. Wilson

MYB26 regulates anther secondary thickening via NST1 and NST2 specifically in the endothecium through a series of regulatory controls.

333

[OPEN] Linking Auxin with Photosynthetic Rate via Leaf Venation. Scott A. M. McAdam, Morgane P. Eléouët, Melanie Best, Timothy J. Brodribb, Madeline Carins Murphy, Sam D. Cook, Marion Dalmais, Theodore Dimitriou, Ariane Gélinas-Marion, Warwick M. Gill, Matthew Hegarty, Julie M. I. Hofer, Mary Maconochie, Erin L. McAdam, Peter McGuinness, David S. Nichols, John J. Ross, Frances C. Susmilch, and Shelley Urquhart

Auxin influences maximum leaf photosynthetic rate through leaf venation and thus water transport capacity.

351

[OPEN] Cytokinin Biosynthesis Promotes Cortical Cell Responses during Nodule Development. Dugald Reid, Marcin Nadzieja, Ondřej Novák, Anne B. Heckmann, Niels Sandal, and Jens Stougaard

Analysis of biosynthesis genes identifies de novo biosynthesis of a cortical cytokinin pool during nodule development.

361

[OPEN] Genetic Architecture and Molecular Networks Underlying Leaf Thickness in Desert-Adapted Tomato *Solanum pennellii*. Viktoriya Coneva, Margaret H. Frank, Maria A. de Luis Balaguer, Mao Li, Rosangela Sozzani, and Daniel H. Chitwood

Leaf thickness in desert-adapted tomato is characterized by the anatomic and transcriptional alterations that are uncovered by QTL analysis of introgression lines.

376

SIGNALING AND RESPONSE

[OPEN] Enhanced Secondary- and Hormone Metabolism in Leaves of Arbuscular Mycorrhizal *Medicago truncatula*. Lisa Adolfsson, Hugues Nziengui, Ilka N Abreu, Jan Šimura, Azeez Beebo, Andrei Herdean, Jila Aboalizadeh, Jitka Široká, Thomas Moritz, Ondřej Novák, Karin Ljung, Benoît Schoefs, and Cornelia Spetea

Mycorrhization and phosphate fertilization share cytokinin-improved shoot growth, while enhanced abscisic acid biosynthesis and jasmonate-regulated secondary metabolism are specific to mycorrhization.

392

[OPEN] Root Bending Is Antagonistically Affected by Hypoxia and ERF-Mediated Transcription via Auxin Signaling. Emese Eysholdt-Derzsó and Margret Sauter

Arabidopsis seedlings display root bending as an escape response to hypoxic conditions that is enhanced by auxin and restricted by the ERFVII transcription factor RAP2.12.

412

[^{OPEN}] Calcium Pumps and Interacting BON1 Protein Modulate Calcium Signature, Stomatal Closure, and Plant Immunity. Dong-Lei Yang, Zhenying Shi, Yongmei Bao, Jiawei Yan, Ziyuan Yang, Huiyun Yu, Yun Li, Mingyue Gou, Shu Wang, Baohong Zou, Dachao Xu, Zhiqi Ma, Jitae Kim, and Jian Hua

Calcium pumps ACA10 and ACA8 and their interacting protein BON1 regulate calcium signatures and impact stomatal movement and plant immunity in Arabidopsis.

424

BcXYG1, a Secreted Xyloglucanase from *Botrytis cinerea*, Triggers Both Cell Death and Plant Immune Responses. Wenjun Zhu, Mordechi Ronen, Yonatan Gur, Anna Minz-Dub, Gal Masrati, Nir Ben-Tal, Alon Savidor, Itai Sharon, Elad Eizner, Oliver Valerius, Gerhard H. Braus, Kyle Bowler, Maor Bar-Peled, and Amir Sharon

A cell death-inducing apoplastic protein facilitates necrosis and establishment of the pathogen Botrytis cinerea but also is recognized by the plant immune system and triggers a defense response.

438

[^{OPEN}] Novel Stress-Inducible Antisense RNAs of Protein-Coding Loci Are Synthesized by RNA-Dependent RNA Polymerase. Akihiro Matsui, Kei Iida, Maho Tanaka, Katsushi Yamaguchi, Kayoko Mizuhashi, Jong-Myong Kim, Satoshi Takahashi, Norio Kobayashi, Shuji Shigenobu, Kazuo Shinozaki, and Motoaki Seki

Stress-inducible non-coding antisense RNAs generated by RNA-dependent RNA polymerases function in a novel abiotic stress response mechanism different from the known endogenous small RNA pathways.

457

[^{OPEN}] Triphosphate Tunnel Metalloenzyme Function in Senescence Highlights a Biological Diversification of This Protein Superfamily. Huo Ung, Purva Karia, Kazuo Ebine, Takashi Ueda, Keiko Yoshioka, and Wolfgang Moeder

The Arabidopsis triphosphate tunnel metalloenzymes AtTTM1 and AtTTM2 are mitochondrial tail-anchored proteins that display the same biochemical properties but distinct biological functions in senescence and pathogen resistance.

473

Phospholipid:Diacylglycerol Acyltransferase-Mediated Triacylglycerol Synthesis Augments Basal Thermotolerance. Stephanie P. Mueller, Melissa Unger, Lena Guender, Agnes Fekete, and Martin J. Mueller

A heat-induced metabolic response independent of the genetically programmed heat-shock response increases heat resistance of Arabidopsis seedlings.

486

[^{OPEN}] Sequence Exchange between Homologous NB-LRR Genes Converts Virus Resistance into Nematode Resistance, and Vice Versa. Erik Sloatweg, Kamila Koropacka, Jan Roosien, Robert Dees, Hein Overmars, Rene Klein Lankhorst, Casper van Schaik, Rikus Pomp, Liesbeth Bouwman, Johannes Helder, Arjen Schots, Jaap Bakker, Geert Smant, and Aska Goverse

Domain swapping between the NB-LRR immune receptors Rx1 and Gpa2 converts extreme resistance to potato virus X in the shoots into potato cyst nematode resistance in the roots, and vice versa.

498

5-Aminolevulinic Acid Dehydratase Gene Dosage Affects Programmed Cell Death and Immunity. Qichao Chai, Xiaoguang Shang, Shuang Wu, Guozhong Zhu, Chaoze Cheng, Caiping Cai, Xinyu Wang, and Wangzhen Guo

Down-regulation of 5-aminolevulinic acid dehydratase encoding genes results in elevated levels of reactive oxygen species, salicylic acid and resistance to Verticillium dahliae infection of cotton.

511

Continued from preceding page

Determining the Site of Action of Strigolactones during Nodulation. *Erin L. McAdam, Cassandra Hugill, Sebastien Fort, Eric Samain, Sylvain Cottaz, Noel W. Davies, James B. Reid, and Eloise Foo*

The plant hormone strigolactone promotes infection thread formation but does not appear to influence other stages of nodulation, including nitrogen fixation.

529

POSITIVE REGULATOR OF IRON HOMEOSTASIS1, OsPRI1, Facilitates Iron Homeostasis. *Huimin Zhang, Yang Li, Xiani Yao, Gang Liang, and Diqiu Yu*

OsPRI1 functions downstream of the Fe-binding sensor OsHRZ1 and directly controls the expression of OsIRO2 and OsIRO3 for iron homeostasis in rice.

543

[OPEN] Proline Accumulation Is Regulated by Transcription Factors Associated with Phosphate Starvation. *Dávid Aleksza, Gábor V. Horváth, Györgyi Sándor, and László Szabados*

Proline accumulation and activation of the P5CS1 gene is an ABA-dependent molecular response to phosphate starvation in Arabidopsis and is controlled by the PHR1 and PHL1 transcription factors.

555

SYSTEMS AND SYNTHETIC BIOLOGY

[OPEN] Construction and Optimization of a Large Gene Coexpression Network in Maize Using RNA-Seq Data. *Ji Huang, Stefania Vendramin, Lizhen Shi, and Karen M. McGinnis*

Large-scale maize coexpression network from RNA-Seq data facilitates gene function and pathway analysis.

568

[CC-BY] Article free via Creative Commons CC-BY 4.0 license.

[OPEN] Articles can be viewed without a subscription.