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Auxin Activity in a Developing Soybean Nodule

The electronic form of this issue, available as of August 7, 2013, at www.plantphysiol.org, is considered the journal of record.

On the Cover: The roles of auxin in symbiotic nodule development are not clearly understood. In this issue, Turner et al. (pp. 2042–2055) show that there is very low auxin activity during nodule formation in soybean (*Glycine max*) and that it changes in a spatiotemporal manner during subsequent nodule development. By manipulating auxin sensitivity using microRNAs, they demonstrate that hypersensitivity to auxin inhibits nodule development likely via modulation of cytokinin sensitivity. Their results suggest a feedback loop involving auxin, cytokinin, and miR160, that governs nodule development. The cover image is a laser confocal optical section of a developing soybean nodule expressing the auxin-responsive marker gene construct, DR5:tdT. Cotransformation of a constitutively expressed sUbi:GFP construct helped distinguish autofluorescence on the root surface (appearing bright red) from marker gene expression (appearing yellowish-red). Photo credit: Narasimha Rao Nizampatnam.

ON THE INSIDE

Peter V. Minorsky

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EDITORIAL

Plant Physiology Welcomes Its New Topical Reviews. Mike Blatt

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TOPICAL REVIEWS

The Agony of Choice: How Plants Balance Growth and Survival under Water-Limiting Conditions. Hannes Claeys and Dirk Inzé

A comprehensive overview is presented of the effects of water limitation on growing shoot tissues, with a focus on molecular mechanisms and networks restricting growth, adaptations for maintained growth, and the molecular interplay between growth and stress tolerance with potential for crop engineering.

1768

Improving Photosynthesis. John R. Evans

Photosynthesis is the basis of plant growth, and it is argued that improving photosynthesis can contribute toward greater food security in the coming decades as world population increases.

1780

BREAKTHROUGH TECHNOLOGIES

^{[C][OPEN]}*Measuring Arabidopsis Chromatin Accessibility Using DNase I-Polymerase Chain Reaction and DNase I-Chip Assays. Huan Shu, Wilhelm Gruitsem, and Lars Hennig*

Differential DNA accessibility, which is established by local chromatin environments and strongly affects gene expression, can be assayed utilizing DNase I digestion coupled to detection by PCR or on tiling arrays.

1794

^{[C][W]}*RootNav: Navigating Images of Complex Root Architectures. Michael P. Pound, Andrew P. French, Jonathan A. Atkinson, Darren M. Wells, Malcolm J. Bennett, and Tony Pridmore*

RootNav is a novel image analysis tool that facilitates the accurate recovery of root system architectures from images.

1802

^{[C][W]}*An Improved Simplified High-Sensitivity Quantification Method for Determining Brassinosteroids in Different Tissues of Rice and Arabidopsis. Peiyong Xin, Jijun Yan, Jinshi Fan, Jinfang Chu, and Cunyu Yan*

A simple and high-sensitivity quantitation strategy based on simplified extraction, purification, and derivatization processes enables quantification of brassinosteroids in small amounts of plant tissue.

2056

RESEARCH REPORTS

[W][OPEN]Export of Salicylic Acid from the Chloroplast Requires the Multidrug and Toxin Extrusion-Like Transporter EDS5. Mario Serrano, Banjung Wang, Bibek Aryal, Christophe Garcion, Eliane Abou-Mansour, Silvia Heck, Markus Geisler, Felix Mauch, Christiane Nawrath, and Jean-Pierre Métraux

The synthesis of the immune signal salicylic acid is abolished by a mutation in a hitherto unknown transporter protein. This article describes the transporter localization at the chloroplast and its function in the export of salicylic acid from the chloroplast.

1815

RESEARCH ARTICLES

BIOCHEMISTRY AND METABOLISM

[W][OPEN]Dynamic Adaption of Metabolic Pathways during Germination and Growth of Lily Pollen Tubes after Inhibition of the Electron Transport Chain. Gerhard Obermeyer, Lena Fragner, Veronika Lang, and Wolfram Weckwerth

Pollen metabolism shows a dynamic transition from pollen grain germination to pollen tube growth and can quickly compensate inhibition of the oxidative phosphorylation.

1822

[W]Transcriptomic and Metabolic Changes Associated with Photorespiratory Ammonium Accumulation in the Model Legume *Lotus japonicus*. Carmen M. Pérez-Delgado, Margarita García-Calderon, Diego H. Sánchez, Michael K. Udvardi, Joachim Kopka, Antonio J. Márquez, and Marco Betti

Transcriptomic and metabolomic analysis of a plastidic glutamine synthetase mutant shows a coordinate repression of photorespiratory genes and accumulation of several key metabolites.

1834

[W][OPEN]Simultaneous Application of Heat, Drought, and Virus to Arabidopsis Plants Reveals Significant Shifts in Signaling Networks. Christian Maximilian Prasch and Uwe Sonnewald

Arabidopsis plants exposed to triple stress are characterized by transcript responses not predictable from single stress treatments that significantly alter the expression of genes involved in signaling and defense processes.

1849

[W][OPEN]A Rice Virescent-Yellow Leaf Mutant Reveals New Insights into the Role and Assembly of Plastid Caseinolytic Protease in Higher Plants. Hui Dong, Gui-Lin Fei, Chuan-Yin Wu, Fu-Qing Wu, Yu-Ying Sun, Ming-Jiang Chen, Yu-Long Ren, Kun-Neng Zhou, Zhi-Jun Cheng, Jiu-Lin Wang, Ling Jiang, Xin Zhang, Xiu-Ping Guo, Cai-Lin Lei, Ning Su, Haiyang Wang, and Jian-Min Wan

Disruption of the OsClpP6 gene causes a virescent-yellow leaf phenotype, demonstrating an important role of caseinolytic proteases in regulating chloroplast biogenesis and leaf development in rice.

1867

[C][W][OPEN]Pepper Arginine Decarboxylase Is Required for Polyamine and γ -Aminobutyric Acid Signaling in Cell Death and Defense Response. Nak Hyun Kim, Beom Seok Kim, and Byung Kook Hwang

Pepper arginine decarboxylase, CaADC1, which interacts with Xanthomonas effector AvrBsT, induces increased polyamine and γ -aminobutyric acid levels, and triggers nitric oxide and reactive oxygen species bursts, ultimately leading to plant cell death and defense responses.

2067

CELL BIOLOGY

[W][OPEN]Following Vegetative to Embryonic Cellular Changes in Leaves of Arabidopsis Overexpressing LEAFY COTYLEDON2. Mistianne Feeney, Lorenzo Frigerio, Yuhai Cui, and Rima Menassa

A transcription factor triggers embryonic characteristics in Arabidopsis vegetative organs.

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Continued on next page

- [C][W][OPEN] HAPLESS13, the Arabidopsis μ 1 Adaptin, Is Essential for Protein Sorting at the trans-Golgi Network/Early Endosome. *Jia-Gang Wang, Sha Li, Xin-Ying Zhao, Liang-Zi Zhou, Guo-Qiang Huang, Chong Feng, and Yan Zhang*
- HAPLESS13 is the Arabidopsis 1μ adaptin protein and affects multiple developmental and cellular processes by sorting membrane proteins, including auxin and brassinosteroid signaling elements, at the trans-Golgi network/early endosome.* 1897
- [W][OPEN] Visualization of BRI1 and BAK1(SERK3) Membrane Receptor Heterooligomers during Brassinosteroid Signaling. *Christoph A. Bücherl, G. Wilma van Esse, Alex Kruis, Jeroen Luchtenberg, Adrie H. Westphal, José Aker, Arie van Hoek, Catherine Albrecht, Jan Willem Borst, and Sacco C. de Vries*
- Initiation of brassinosteroid signal transduction involves a small number of preassembled BRI1-BAK1(SERK3) heterooligomers.* 1911
- [C][W][OPEN] Identification of a New Class of Lipid Droplet-Associated Proteins in Plants. *Patrick J. Horn, Christopher N. James, Satinder K. Gidda, Aruna Kilaru, John M. Dyer, Robert T. Mullen, John B. Ohlrogge, and Kent D. Chapman*
- A new class of lipid droplet-associated proteins in nonseed tissues is identified by integrated omics approaches.* 1926

ECOPHYSIOLOGY AND SUSTAINABILITY

- [W][OPEN] Characterization of *AtSTOP1* Orthologous Genes in Tobacco and Other Plant Species. *Yoshinao Ohyama, Hiroki Ito, Yuriko Kobayashi, Takashi Ikka, Akio Morita, Masatomo Kobayashi, Ryujiro Imaizumi, Toshio Aoki, Kenji Komatsu, Yoichi Sakata, Satoshi Iuchi, and Hiroyuki Koyama*
- Diverse land plant species possess similar proteins that function in transcriptional regulation of aluminum tolerance.* 1937
- [C][W][OPEN] Coordination between Apoplastic and Symplastic Detoxification Confers Plant Aluminum Resistance. *Xiao Fang Zhu, Gui Jie Lei, Zhi Wei Wang, Yuan Zhi Shi, Janet Braam, Gui Xin Li, and Shao Jian Zheng*
- Plants must coordinate exclusion and internal detoxification to reduce aluminum toxicity effectively.* 1947
- [OPEN] Ocean Acidification Alters the Photosynthetic Responses of a Coccolithophorid to Fluctuating Ultraviolet and Visible Radiation. *Peng Jin, Kunshan Gao, Virginia E. Villafañe, Douglas A. Campbell, and E. Walter Helbling*
- Ocean acidification and fast mixing or fluctuation of solar radiation could act synergistically to lower carbon fixation by *G. oceanica*, though ocean acidification may decrease UVB-related photochemical inhibition.* 2084
- [C][W][OPEN] Nitrogen Stress Affects the Turnover and Size of Nitrogen Pools Supplying Leaf Growth in a Grass. *Christoph Andreas Lehmeier, Melanie Wild, and Hans Schnyder*
- Nitrogen stress has strong effects on the size and turnover of nitrogen pools supplying leaf growth of a grass but does not alter the relative contributions of currently assimilated and remobilized nitrogen for leaf growth.* 2095

GENES, DEVELOPMENT, AND EVOLUTION

- [C] Disruption of Fumarylacetoacetate Hydrolase Causes Spontaneous Cell Death under Short-Day Conditions in Arabidopsis. *Chengyun Han, Chunmei Ren, Tiantian Zhi, Zhou Zhou, Yan Liu, Feng Chen, Wen Peng, and Daoxin Xie*
- Disrupting fumarylacetoacetate hydrolase leads to cell death in Arabidopsis, indicating that the Tyr degradation pathway is essential for plant survival under short-day conditions.* 1956
- [W][OPEN] Brassinosteroid Regulates Seed Size and Shape in Arabidopsis. *Wen-Bo Jiang, Hui-Ya Huang, Yu-Wei Hu, Sheng-Wei Zhu, Zhi-Yong Wang, and Wen-Hui Lin*
- Brassinosteroid regulates Arabidopsis seed size and shape by transcriptionally modulating specific seed developmental pathways.* 1965

[C][W][OPEN] ERECTA Family Genes Regulate Auxin Transport in the Shoot Apical Meristem and Forming Leaf Primordia. *Ming-Kun Chen, Rebecca L. Wilson, Klaus Palme, Franck Anicet Ditengou, and Elena D. Shpak*

ERECTA family receptors are involved in the regulation of phyllotaxy and leaf initiation.

1978

SIGNALING AND RESPONSE

[W][OPEN] Cross-Repressive Interactions between SOC1 and the GATAs GNC and GNL/CGA1 in the Control of Greening, Cold Tolerance, and Flowering Time in Arabidopsis. *René Richter, Emmanouil Bastakis, and Claus Schwechheimer*

The transcription factor SOC1 is regulated by two GATA transcription factors for the control of flowering while the GATAs are controlled by SOC1 to control greening and cold tolerance.

1992

[W] The Alteration of Plant Morphology by Small Peptides Released from the Proteolytic Processing of the Bacterial Peptide TENGU. *Kyoko Sugawara, Youhei Honma, Ken Komatsu, Misako Himeno, Kenro Oshima, and Shigetou Namba*

A bacterial peptide effector undergoes proteolytic processing in plants and releases small peptides that alter plant morphology.

2005

[C][W] Transient Transcriptional Regulation of the CYS-C1 Gene and Cyanide Accumulation upon Pathogen Infection in the Plant Immune Response. *Irene García, Tábata Rosas, Eduardo R. Bejarano, Cecilia Gotor, and Luis C. Romero*

The analysis of a mutant in the main enzyme responsible for cyanide detoxification, the mitochondrial β -cyanoalanine synthase, uncovers a new signaling role for cyanide in the plant response to pathogens.

2015

[C][W][OPEN] Identification of Genes Involved in the Response of Arabidopsis to Simultaneous Biotic and Abiotic Stresses. *Nicky J. Atkinson, Catherine J. Lilley, and Peter E. Urwin*

Arabidopsis responds to simultaneous water stress and nematode infection by activating a unique program of gene expression that is distinct from the response to individual stresses.

2028

[W][OPEN] Ectopic Expression of miR160 Results in Auxin Hypersensitivity, Cytokinin Hyposensitivity, and Inhibition of Symbiotic Nodule Development in Soybean. *Marie Turner, Narasimha Rao Nizampatnam, Mathieu Baron, Stéphanie Coppin, Suresh Damodaran, Sajag Adhikari, Shivaram Poigai Arunachalam, Oliver Yu, and Senthil Subramanian*

Analysis of symbiotic nodulation indicates low auxin activity and auxin hypersensitivity during nodule initiation, and regulatory feedback with auxin and cytokinin during nodule development.

2042

[C][W][OPEN] The HERBIVORE ELICITOR-REGULATED1 Gene Enhances Abscisic Acid Levels and Defenses against Herbivores in *Nicotiana attenuata* Plants. *Son Truong Dinh, Ian T. Baldwin, and Ivan Galis*

By enhancing abscisic acid levels, a novel herbivore elicitor-regulated protein plays an essential role in efficient defense of metabolite accumulation against herbivores in plants.

2106

[C][W][OPEN] Lifting DELLA Repression of Arabidopsis Seed Germination by Nonproteolytic Gibberellin Signaling. *Tohru Ariizumi, Amber L. Hauwemale, Sven K. Nelson, Atsushi Hanada, Shinjiro Yamaguchi, and Camille M. Steber*

GA signaling controls seed germination in the sly1 mutant background, in which DELLA repressors cannot be destroyed by the ubiquitin-proteasome pathway.

2125

SYSTEMS AND SYNTHETIC BIOLOGY

[C][W][OPEN] Elucidating Rice Cell Metabolism under Flooding and Drought Stresses Using Flux-Based Modeling and Analysis. *Meiyappan Lakshmanan, Zhaoyang Zhang, Bijayalaxmi Mohanty, Jun-Young Kwon, Hong-Yeol Choi, Hyung-Jin Nam, Dong-Il Kim, and Dong-Yup Lee*

A metabolic/regulatory network of rice incorporates two important tissue types, germinating seeds and photorespiring leaves, is validated through experiments with rice suspension cultures, and applied to analyze metabolic capability under flooding and drought conditions.

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ADDENDA

Characterization of SOC1's Central Role in Flowering by the Identification of Its Upstream and Downstream Regulators. *Immink R.G.H., Posé D., Ferrario S., Ott F., Kaufmann K., Valentim F.L., de Folter S., van der Wal F., van Dijk A.D.J., Schmid M., and Angenent G.C*

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