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

**EDITORIAL**


**TOPICAL REVIEWS**


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.

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.

**BREAKTHROUGH TECHNOLOGIES**


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.


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

[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.
RESEARCH REPORTS

Export of Salicylic Acid from the Chloroplast Requires the Multidrug and Toxin Extrusion-Like Transporter EDS5. Mario Serrano, Banjung Wang, Bibek Aryal, Christophe Garciaion, Eliane Abou-Mansour, Silvia Heck, Markus Geisler, Felix Mauch, Christiane Naourath, 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.

RESEARCH ARTICLES

BIOCHEMISTRY AND METABOLISM

Dynamic Adaptation 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.


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

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.


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.

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.

CELL BIOLOGY

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.
HAPLESS13, the Arabidopsis μ1 Adaptin, Is Essential for Protein Sorting at the trans-Golgi Network/Early Endosome. Jia-Gang Wang, Shu Li, Xin-Ying Zhao, Liang-Zi Zhou, Guo-Qiang Huang, Chong Feng, and Yan Zhang

HAPLESS13 is the Arabidopsis μ1 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.

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.


A new class of lipid droplet-associated proteins in nonseed tissues is identified by integrated omics approaches.

ECOPHYSIOLOGY AND SUSTAINABILITY

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.

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.

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.

Nitrogen Stress Affects the Turnover and Size of Nitrogen Pools Supplying Leaf Growth in a Grass. Christoph Andreas Lehmaier, Melanie Wild, and Hans Schneider

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.

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.

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.
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 Dilengou, and Elena D. Shpak

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

1978

SIGNALING AND RESPONSE

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

The Alteration of Plant Morphology by Small Peptides Released from the Proteolytic Processing of the Bacterial Peptide TENGU.  
Kyoko Sugawara, Youhei Homma, 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

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

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

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, Saajg 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

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

Lifting DELLA Repression of Arabidopsis Seed Germination by Nonproteolytic Gibberellin Signaling.  
Tohru Ariizumi, Amber L. Hauvermale, 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
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.

ADDENDA


[C] Some figures in this article are displayed in color online but in black and white in the print edition.  
[W] Indicates Web-only data.  
[OPEN] Access articles can be viewed online without a subscription.