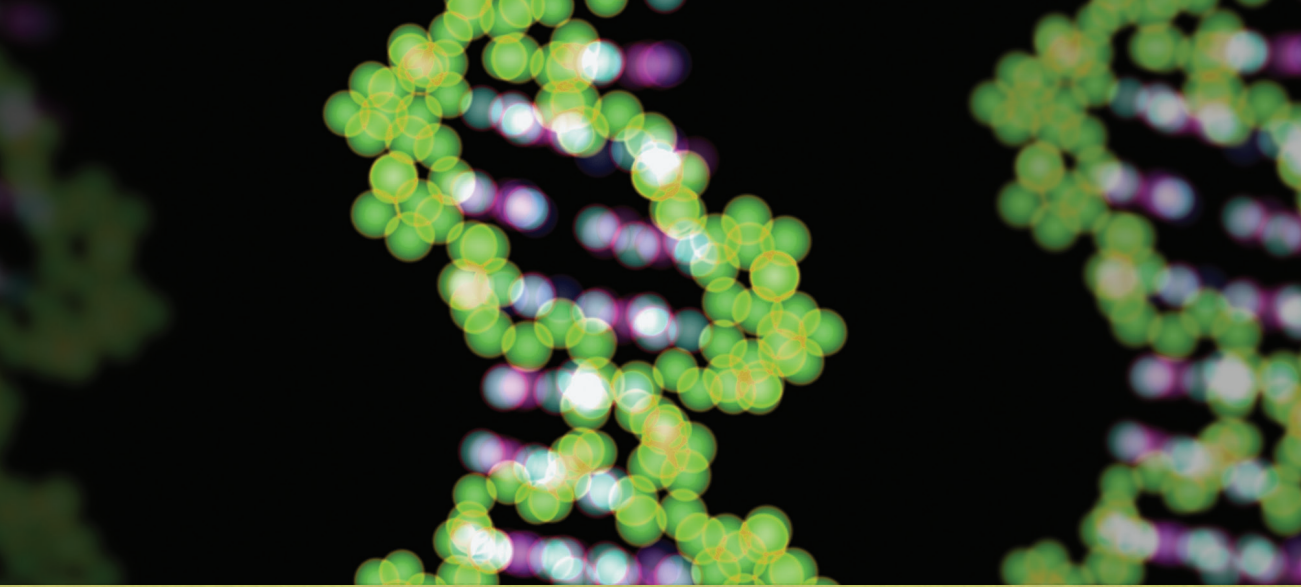
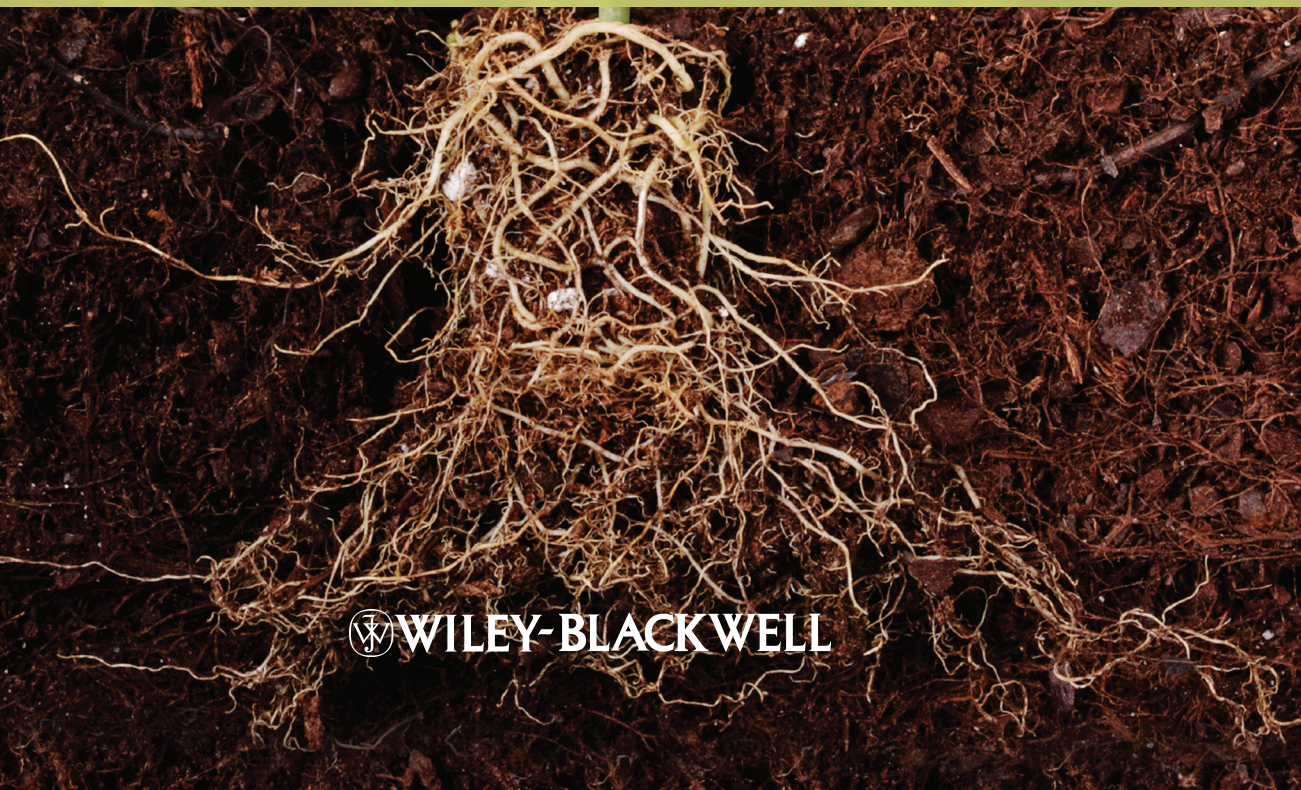




Root Genomics and Soil Interactions

Edited by Martin Crespi



 WILEY-BLACKWELL

Root Genomics and Soil Interactions

Root Genomics and Soil Interactions

Edited by
MARTIN CRESPI

 **WILEY-BLACKWELL**

A John Wiley & Sons, Inc., Publication

This edition first published 2013 © 2013 by John Wiley & Sons, Inc.

Wiley-Blackwell is an imprint of John Wiley & Sons, formed by the merger of Wiley's global Scientific, Technical and Medical business with Blackwell Publishing.

Editorial offices: 2121 State Avenue, Ames, Iowa 50014-8300, USA
The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK
9600 Garsington Road, Oxford, OX4 2DQ, UK

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at www.wiley.com/wiley-blackwell.

Authorization to photocopy items for internal or personal use, or the internal or personal use of specific clients, is granted by Blackwell Publishing, provided that the base fee is paid directly to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923. For those organizations that have been granted a photocopy license by CCC, a separate system of payments has been arranged. The fee codes for users of the Transactional Reporting Service are ISBN-13: 978-0-4709-6043-1/2013.

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book. This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold on the understanding that the publisher is not engaged in rendering professional services. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

Library of Congress Cataloging-in-Publication Data

Root genomics and soil interactions / editor, Martin Crespi.

p. cm.

Includes bibliographical references and index.

ISBN 978-0-470-96043-1 (hardback : alk. paper)

1. Roots (Botany)—Physiology. 2. Roots (Botany)—Development. 3. Plant genomes. 4. Genomics.
5. Plant-soil relationships. I. Crespi, Martin.

QK644.R6523 2012

575.5'4—dc23

2012021109

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Cover design by Modern Alchemy LLC

Set in 10.5/12 pt Times by Aptara® Inc., New Delhi, India

1 2013

Contents

Contributors	ix
Preface	xv
Chapter 1 Genomics of Root Development	3
Boris Parizot and Tom Beeckman	
Introduction	3
Genomics of LRI	7
Rise of New Technologies to Understand Lateral Root Development	19
ComparativOmics, the Future	20
Acknowledgments	21
References	21
Chapter 2 The Complex Eukaryotic Transcriptome: Nonprotein-Coding RNAs and Root Development	29
F. Ariel, A.B. Moreno, F. Bardou, and M. Crespi	
Genomic Approaches Reveal Novel Aspects of the Eukaryotic Transcriptome	29
The Role of RNA-Binding Proteins in npcRNA Metabolism and Activity	34
Nonprotein-Coding RNAs in Root Development	38
Future Perspectives	42
Acknowledgments	42
References	42
Chapter 3 Genomics of Auxin Action in Roots	49
Elisabeth L. Williams and Ive De Smet	
Introduction	49
The Basis of Auxin Biology	49
Auxin Genomics in Root Development	55
Auxin and Root Hair Development	56
Auxin in Gravitropism	57
Auxin in LR Initiation	57
Conclusion	58
Acknowledgments	58
References	58

Chapter 4	Cell-Type Resolution Analysis of Root Development and Environmental Responses	63
	José R. Dinneny	
	Introduction	63
	Tools for Cell-Type Resolution Analysis	64
	Analysis of Spatiotemporal Expression Patterns in the Arabidopsis Root	69
	Analysis of Cell-Type-Specific Expression Patterns in the Rice Root	70
	Cell-Type-Specific Analysis of Auxin	71
	Cell-Type-Specific Analyses of Chromatin	71
	Cell-Type-Specific Analyses of Responses to Environmental Change	72
	Future Prospects	76
	Acknowledgments	76
	References	77
Chapter 5	Toward a Virtual Root: Interaction of Genomics and Modeling to Develop Predictive Biology Approaches	79
	Julien Lavenus, Leah Band, Alistair Middleton, Michael Wilson, Mikael Lucas, Laurent Laplace, and Malcolm Bennett	
	Assembling Root Gene Regulatory Pathways Using Genomics	79
	Modeling Well-Characterized Small Root Gene Regulatory Networks	81
	Building New Large-Scale Root Gene Regulatory Network	84
	Multi-Scale Modeling Approaches to Study Root Growth and Development	88
	Conclusions and Future Challenges	89
	References	91
Chapter 6	Genomics of Root Hairs	93
	Hyung-Taeg Cho	
	Genomics with Single Cells	93
	Root Hair Development	94
	High-Throughput Approaches for the Characterization of Root Hairs	95
	Functions of Root Hair-Specific Genes	103
	The Regulatory Pathway for Root Hair-Specific Genes	110
	Perspective	111
	Acknowledgments	111
	References	112
Chapter 7	The Effects of Moisture Extremes on Plant Roots and Their Connections with Other Abiotic Stresses	117
	Laura M. Vaughn and Henry T. Nguyen	
	Introduction	117
	Low Water Availability—Drought	118
	Excess Water—Soil Waterlogging, Flooding, and Submergence	128
	Common Plant Root Responses to Abiotic Stressors	135

	Continuing Challenges in Breeding for Plant Root Systems Tolerant to Abiotic Stress	137
	Acknowledgments	138
	References	138
Chapter 8	Legume Roots and Nitrogen-Fixing Symbiotic Interactions	145
	Philippe Laporte, Andreas Niebel, and Florian Frugier	
	Genetic Dissection of the Legume Root System	145
	Functional Genomic Analyses of Legume Nodules and Roots	155
	Concluding Remarks	161
	Acknowledgments	162
	References	162
Chapter 9	What the Genomics of Arbuscular Mycorrhizal Symbiosis Teaches Us about Root Development	171
	Damien Formey, Cyril Jourda, Christophe Roux, and Pierre-Marc Delaux	
	Forward and Reverse Genetics for Identifying Myc Mutants	172
	Comparative Transcriptomics of AM Symbiosis: Toward Identification of Genes Involved in Root Development	175
	Small RNAs in AM Symbiosis	181
	Acknowledgments	183
	References	183
Chapter 10	How Pathogens Affect Root Structure	189
	Michaël Quentin, Tarek Hewezi, Isabelle Damiani, Pierre Abad, Thomas Baum, and Bruno Favery	
	Introduction	189
	Root Infection and Feeding Cell Ontogenesis	190
	Genome-Wide Analysis of the Plant Response to Infection	192
	The Plant Cytoskeleton Is Targeted by Root Pathogens	193
	Root Pathogens Hijack Cell Cycle Regulators	194
	Severe Cell Wall Remodeling Is Associated with Feeding Site Formation	195
	Phytohormones Regulating Development and Defense May Control Feeding Site Formation	196
	Role of miRNAs in Feeding Site Formation and Function	198
	Nematode Effectors That Alter Root Cell Development during Parasitism	200
	Conclusion	203
	Acknowledgments	204
	References	204
Chapter 11	Genomics of the Root—Actinorhizal Symbiosis	211
	Valérie Hocher, Nicole Alloisio, Laurent Laplaze, Didier Bogusz, and Philippe Normand	
	Introduction	211
	Actinorhizal Symbiosis	212

	Development of Actinorhizal Nodules	214
	Genomic Resources for Studying Actinorhizal Symbiosis	217
	What Did We Learn from Actinorhizal Genomics?	220
	Conclusion and Future Directions	222
	Acknowledgments	222
	References	223
Chapter 12	Plant Growth Promoting Rhizobacteria and Root Architecture	227
	Thais L.G. Carvalho, Paulo C.G. Ferreira, and Adriana S. Hemerly	
	Introduction	227
	Different Root Niches for PGPR Colonization	228
	PGPR Recognition by Plants	229
	Modulation of Root Growth and Architecture by PGPRs	232
	Mechanisms of Plant Growth Promotion by PGPRs	234
	Plant Genetic Programs Controlling Modulation of Root Growth and Architecture by PGPRs	240
	Conclusions	241
	Acknowledgments	242
	References	242
Chapter 13	Translational Root Genomics for Crop Improvement	249
	Reyazul Rouf Mir, Mahendar Thudi, Siva K. Chamarthi, L. Krishnamurthy, Pooran M. Gaur, and Rajeev K. Varshney	
	Introduction	249
	Molecular Dissection of Root Trait	258
	Molecular Breeding for Root Traits	259
	Summary and Outlook	260
	Acknowledgments	260
	References	260
Index		265

Color plate located between pages 144 and 145

Contributors

Pierre Abad	INRA-CNRS-Université de Nice Sophia-Antipolis Interactions Biotiques et Santé Végétale Sophia Antipolis, France
Nicole Alloisio	Centre National de la Recherche Scientifique Ecologie Microbienne Université de Lyon Cedex Villeurbanne, France
F. Ariel	Institut des Sciences du Végétal Centre National de la Recherche Scientifique Gif sur Yvette cedex, France
Leah Band	Centre for Plant Integrative Biology University of Nottingham United Kingdom
F. Bardou	Institut des Sciences du Végétal Centre National de la Recherche Scientifique Gif sur Yvette cedex, France
Thomas Baum	Department of Plant Pathology and Microbiology Iowa State University Ames, Iowa, USA
Tom Beeckman	Department of Plant Systems Biology and Department of Plant Biotechnology and Genetics Ghent University Ghent, Belgium
Malcolm Bennett	Centre for Plant Integrative Biology University of Nottingham United Kingdom
Didier Bogusz	Equipe Rhizogenèse Institut de Recherche pour le Développement Montpellier, France

Thais L.G. Carvalho	Laboratório de Biologia Molecular de Plantas Instituto de Bioquímica Médica Universidade Federal do Rio de Janeiro Rio de Janeiro, Brazil
Siva K. Chamarthi	International Crops Research Institute for the Semi-Arid Tropics Hyderabad, India
Hyung-Taeg Cho	Department of Biological Sciences and Genomics and Breeding Institute Seoul National University Seoul, Korea
Martin Crespi	Institut des Sciences du Végétal Centre National de la Recherche Scientifique Gif sur Yvette cedex, France
Isabelle Damiani	INRA-CNRS-Université de Nice Sophia-Antipolis Interactions Biotiques et Santé Végétale Sophia Antipolis, France
Pierre-Marc Delaux	Laboratoire de Recherche en Sciences Végétales Université de Toulouse Castanet-Tolosan, France
José R. Dinneny	Carnegie Institution for Science Department of Plant Biology Stanford, California, USA and Temasek Lifesciences Laboratory Department of Biological Sciences National University of Singapore Singapore
Bruno Favery	INRA-CNRS-Université de Nice Sophia-Antipolis Interactions Biotiques et Santé Végétale Sophia Antipolis, France
Paulo C.G. Ferreira	Laboratório de Biologia Molecular de Plantas Instituto de Bioquímica Médica Universidade Federal do Rio de Janeiro Rio de Janeiro, Brazil
Damien Formey	Laboratoire de Recherche en Sciences Végétales Université de Toulouse Castanet-Tolosan, France
Florian Frugier	Institut des Sciences du Végétal (ISV), CNRS Gif-sur-Yvette cedex, France
Pooran M. Gaur	International Crops Research Institute for the Semi-Arid Tropics Hyderabad, India

- Adriana S. Hemerly** Laboratório de Biologia Molecular de Plantas
Instituto de Bioquímica Médica
Universidade Federal do Rio de Janeiro
Rio de Janeiro, Brazil
- Tarek Hewezi** Department of Plant Pathology and Microbiology
Iowa State University
Ames, Iowa, USA
- Valérie Hocher** Equipe Rhizogenèse
Institut de Recherche pour le Développement
Montpellier, France
- Cyril Jourda** Laboratoire de Recherche en Sciences Végétales
Université de Toulouse
Castanet-Tolosan, France
- L. Krishnamurthy** International Crops Research Institute for the Semi-Arid Tropics
Hyderabad, India
- Laurent Laplaze** Equipe Rhizogenèse
Institut de Recherche pour le Développement
Montpellier, France
and
Laboratoire Commun de Microbiologie
Centre de Recherche de Bel Air
Dakar, Sénégal
- Philippe Laporte** Laboratoire des Interactions Plantes Micro-organismes (LIPM) UMR
CNRS-INRA
Castanet-Tolosan Cedex, France
- Julien Lavenus** Centre for Plant Integrative Biology
University of Nottingham
United Kingdom
and
Institut de Recherche pour le Développement
UMR DIADE
Montpellier, France
- Mikael Lucas** Centre for Plant Integrative Biology
University of Nottingham
United Kingdom
and
Institut de Recherche pour le Développement
UMR DIADE
Montpellier, France
- Alistair Middleton** Centre for Plant Integrative Biology
University of Nottingham
United Kingdom

- and
Center for Biological Systems Analysis
Albert-Ludwigs-Universität
Freiburg, Germany
- A.B. Moreno** Institut des Sciences du Végétal
Centre National de la Recherche Scientifique
Gif sur Yvette cedex, France
- Henry T. Nguyen** Division of Plant Sciences
University of Missouri
Columbia, Missouri, USA
and
The National Center for Soybean Biotechnology
- Andreas Niebel** Laboratoire des Interactions Plantes Micro-organismes
UMR CNRS-INRA
Castanet-Tolosan Cedex, France
- Philippe Normand** Centre National de la Recherche Scientifique
Ecologie Microbienne
Université de Lyon
Cedex Villeurbanne, France
- Boris Parizot** Department of Plant Systems Biology and
Department of Plant Biotechnology and Genetics
Ghent University
Ghent, Belgium
- Michaël Quentin** INRA-CNRS-Université de Nice Sophia-Antipolis
Interactions Biotiques et Santé Végétale
Sophia Antipolis, France
- Reyazul Rouf Mir** International Crops Research Institute for the Semi-Arid Tropics
Hyderabad, India
- Christophe Roux** Laboratoire de Recherche en Sciences Végétales
Université de Toulouse
Castanet-Tolosan, France
- Ive De Smet** Division of Plant and Crop Sciences
School of Biosciences
University of Nottingham
Loughborough, United Kingdom
- Mahendar Thudi** International Crops Research Institute for the Semi-Arid Tropics
Hyderabad, India
- Rajeev K. Varshney** International Crops Research Institute for the Semi-Arid Tropics
Hyderabad, India
and

CGIAR-Generation Challenge Programme
DF, Mexico
and
School of Plant Biology
Faculty of Natural and Agricultural Sciences
The University of Western Australia
Crawley, WA, Australia

Laura M. Vaughn

Division of Plant Sciences
University of Missouri
Columbia, Missouri, USA
and
The National Center for Soybean Biotechnology
and
Department of Natural Resources and Environmental Sciences
University of Illinois

Elisabeth L. Williams

Division of Plant and Crop Sciences
School of Biosciences
University of Nottingham
Loughborough, United Kingdom

Michael Wilson

Centre for Plant Integrative Biology
University of Nottingham
United Kingdom