



Plant Gene Research

Basic Knowledge and Application

Edited by

E.S. Dennis, Canberra

B. Hohn, Basel

Th. Hohn, Basel (Managing Editor)

P.J. King, Basel

F. Meins, Jr., Basel

J. Schell, Köln

D.P.S. Verma, Columbus

Springer-Verlag Wien GmbH

Genes Involved in Plant Defense

Edited by

T. Boller and F. Meins

Springer-Verlag Wien GmbH

Dr. Thomas Boller

Botanisches Institut der Universität Basel
Basel

Dr. Frederick Meins, Jr.

Friedrich Miescher Institut
Basel

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically those of translation, reprinting, re-use of illustrations, broadcasting, reproduction by photocopying machine or similar means, and storage in data banks.

© 1992 by Springer-Verlag Wien

Originally published by Springer-Verlag/Wien in 1992

Typeset by Macmillan India Ltd., Bangalore 25

With 34 Figures

Library of Congress Cataloging-in-Publication Data

Genes involved in plant defense / edited by T. Boller and F. Meins.
p. cm.—(Plant gene research, ISSN 0175-2073)

Includes bibliographical references and index.

ISBN 978-3-7091-7380-0 ISBN 978-3-7091-6684-0 (eBook)

DOI 10.1007/978-3-7091-6684-0

1. Plants—Disease and pest resistance—Genetic aspects.

2. Plant diseases—Genetic aspects.

I. Boller, T. (Thomas), 1949– . II. Meins, F. (Frederick), 1942– . III. Series.
SB750.G44 1992 92-20768
632'.3—dc20 CIP

ISSN 0175-2073

ISBN 978-3-7091-7380-0

Preface

Many fungi and bacteria that associate with plants are potentially harmful and can cause disease, while others enter into mutually beneficial symbioses. Co-evolution of plants with pathogenic and symbiotic microbes has led to refined mechanisms of reciprocal recognition, defense and counter-defense. Genes in both partners determine and regulate these mechanisms. A detailed understanding of these genes provides basic biological insights as well as a starting point for developing novel methods of crop protection against pathogens. This volume deals with defense-related genes of plants and their regulation as well as with the genes of microbes involved in their interaction with plants.

Our discussion begins at the level of populations and addresses the complex interaction of plant and microbial genes in multigenic disease resistance and its significance for crop protection as compared to monogenic resistance (Chap. 1). Although monogenic disease resistance may have its problems in the practice of crop protection, it is appealing to the experimentalist: in the so-called gene-for-gene systems, single genes in the plant and in the pathogen specify the compatibility or incompatibility of an interaction providing an ideal experimental system for studying events at the molecular level (Chaps. 2 and 4). Good progress has been made in identifying viral, bacterial, and fungal genes important in virulence and host range (Chaps. 3–6). An important aspect of plant–microbe interactions is the exchange of chemical signals. Microbes can respond to chemical signals of plant origin. This is exemplified by *Agrobacterium* which recognizes plant wound substances and responds by expressing a set of virulence genes (Chap. 7). Plants, on the other hand, recognize substances of microbial origin, so-called elicitors, and these induce an array of defense genes. Chapter 8 discusses the type of elicitor molecules involved, the perception of elicitors by the plant cells, and the transduction of the elicitor signals. The identification of genes induced in plants in the response to potential pathogens and elicitors is a rapidly developing field, and techniques for gene transfer into plants are being used to establish the function of these genes and their regulation. Included in this groups are genes encoding “pathogenesis-related” proteins (Chap. 9), antifungal hydrolases (Chap. 10), thionins (Chap. 11) and key enzymes in the phenylpropanoid pathway leading to the synthesis of several types of phytoalexins (Chap. 12) and lignin (Chap. 13).

The plant’s defense against microbes is a much-studied and rapidly evolving topic. We hope that this volume, with its combination of current

views of epidemiologists, biochemists and molecular biologists and with its emphasis on both plant and microbial genes, will provide a useful framework for future studies. We thank the authors for their excellent contributions and stimulating treatment of this interesting field. We also give special thanks to Sue Thomas who helped us in preparing the volume.

Basel, January 1992

Thomas Boller and Frederick Meins, Jr.

Contents

- Section I *Resistance and Susceptibility Genes of Plants*
- Chapter 1 **The Use of Resistance Genes in Breeding: Epidemiological Considerations**
M.S. Wolfe and C. Gessler , Zürich, Switzerland
- I. Introduction 3
 - II. Current Techniques for Selecting for Disease Resistance 12
 - III. Strategies for Using Resistant Varieties 18
 - IV. New Approaches 19
 - V. Conclusions 21
 - VI. References 21
- Chapter 2 **Functional Models to Explain Gene-for-Gene Relationships in Plant–Pathogen Interactions**
P.J.G.M. de Wit, Wageningen, The Netherlands
- I. Introduction 25
 - II. Physiologic Races and Differentials 26
 - III. Genetic Analysis of Gene-for-Gene Relationships 27
 - IV. Gene-for-Gene Interactions Involving Fungal Pathogenic Bacteria 33
 - V. Gene-for-Gene Interactions Involving Fungal Plant Pathogens 37
 - VI. Conclusion 42
 - VII. References 42
- Section II *Virulence and Avirulence Genes of Pathogens*
- Chapter 3 **An Analysis of Host Range Specificity Genes of *Rhizobium* as a Model System for Virulence Genes in Phytobacteria**
M.A. Djordjevic, B.G. Rolfe, and W. Lewis-Henderson,
Canberra, Australia
- I. Introduction 51
 - II. Genes Required for Plant–Microbe Interactions 54
 - III. *Rhizobium* as a Useful Model System 55
 - IV. Discussion 72
 - V. References 74
- Chapter 4 **Pathogen Avirulence Genes and Elicitors of Plant Defense**
N.T. Keen and W.O. Dawson, Riverside, California, U.S.A.
- I. Introduction 85
 - II. Host Range Determinants 87

- III. General Elicitors 89
 - IV. Suppressors 94
 - V. Specific Elicitors 94
 - VI. Do Plants Contain Receptors That Recognize Elicitors and Initiate the HR? 102
 - VII. Signal Transduction and Defense Gene Activation 104
 - VIII. Conclusions 105
 - IX. References 106
- Chapter 5 **Pathogenicity Determinants in the Smut Fungi of Cereals**
F. Banuett and I. Herskowitz, San Francisco, California, U.S.A.
- I. Introduction 115
 - II. General Aspects of the Life Cycle of the Smut Fungi—With Emphasis on *U. maydis* 116
 - III. The Mating Type Loci of *Ustilago maydis* 119
 - IV. Host–Pathogen Interactions in the Smut Fungi 125
 - V. Conclusion 126
 - VI. References 126
- Chapter 6 **Identification of Fungal Genes Involved in Plant Pathogenesis and Host Range**
W. Schäfer, D. Stahl, and E. Mönke, Berlin, Federal Republic of Germany
- I. Introduction 129
 - II. Transformation of Phytopathogenic Fungi 130
 - III. Gene Cloning Procedures 134
 - IV. Pathogenicity of *Ustilago maydis* 135
 - V. Fungal Penetration of the Plant Cell 136
 - VI. The PDA Gene, a Gene for Pathogenicity and Host Range 140
 - VII. Some Aspects of Further Development in Plant Pathology 145
 - VIII. References 146
- Section III *Perception of Pathogens and Signal Transduction*
- Chapter 7 **Interactions Between *Agrobacterium tumefaciens* and Its Host Plant Cells**
S.C. Winans, Ithaca, New York, U.S.A.
- I. Introduction 155
 - II. An Overview of Crown Gall Tumorigenesis 156
 - III. A Chronology of Tumorigenesis 157
 - IV. References 172
- Chapter 8 **Elicitor Recognition and Signal Transduction**
J. Ebel and D. Scheel, Freiburg and Köln, Federal Republic of Germany
- I. Introduction 183
 - II. Elicitors and Plant Responses 184

- III. Perception of Elicitor Stimulus 189
- IV. Transduction of Elicitor Signal 192
- V. Regulation of Plant Responses 196
- VI. Conclusions 198
- VII. References 199

Section IV *Plant Genes Induced in the Defense Reaction*

Chapter 9 **Pathogenesis-related Proteins**

J.R. Cutt and D.F. Klessig, Piscataway, New Jersey, U.S.A.

- I. Introduction 209
- II. The Tobacco-TMV System 211
- III. Alternative Plant Systems 231
- IV. Conclusions 232
- V. References 233

Chapter 10 **The Primary Structure of Plant Pathogenesis-related Glucanohydrolases and Their Genes**

F. Meins, Jr., J.-M. Neuhaus, C. Sperisen, and J. Ryals,
Basel, Switzerland, and Research Triangle Park,
North Carolina, U.S.A.

- I. Introduction 246
- II. Multiple Isoforms of β -1,3-Glucanase and Chitinase 246
- III. Primary Structure 250
- IV. Genes Encoding Chitinase and β -1,3-Glucanase 261
- V. Conclusion 270
- VI. References 273

Chapter 11 **Characterization and Analysis of Thionin Genes**

F. Garcia-Olmedo, M.J. Carmona, J.J. Lopez-Fando,
J.A. Fernandez, A. Castagnaro, A. Molina, C. Hernandez-
Lucas, and P. Carbonero, Madrid, Spain

- I. Introduction 283
- II. Thionin Types 284
- III. Biosynthesis and Subcellular Location 287
- IV. Structure and Chromosomal Location of Thionin Genes 289
- V. Gene Expression 290
- VI. Antimicrobial Properties and Other In Vitro Activities of Thionins 293
- VII. Possible Implication of Thionins in Plant Defense 297
- VIII. Conclusion and Perspectives 298
- IX. References 299

Chapter 12 **Regulatory Elements Controlling Developmental and Stress-induced Expression of Phenylpropanoid Genes**

J.L. Dangel, Köln, Federal Republic of Germany

- I. Introduction 303
- II. L-Phenylalanine Ammonia-Lyase (PAL) 305
- III. 4-Coumarate: CoA Ligase (4CL) 310

IV. Chalcone Synthase (CHS) 313

V. Perspectives 320

VI. References 321

Chapter 13 Regulation of Lignification in Defense

M.H. Walter, Stuttgart, Federal Republic of Germany

I. Introduction 327

II. Lignin: Matrix Polymer of a Structural Barrier Against Pathogen Ingress 329

III. Regulation of Enzymes in Lignin Biosynthesis 334

IV. Cinnamyl-Alcohol Dehydrogenase—a Committed Enzyme 340

V. Possible Roles of Lignin Monomers and Polymers in the Structural Barrier 344

VI. Perspectives 345

VII. References 346

Subject Index 353