Genes, Genetics and Transgenics for Virus Resistance in Plants

https://doi.org/10.21775/9781910190814

Edited by

Basavaprabhu L. Patil

ICAR-National Research Centre on Plant Biotechnology (NRCPB)
LBS centre, IARI, Pusa campus
New Delhi, India

Caister Academic Press

caister.com/transgenic

Caister Academic Press
Norfolk, UK

www.caister.com

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

ISBN: 978-1-910190-81-4 (paperback)
ISBN: 978-1-910190-82-1 (ebook)

Cover design adapted from images provided by Basavaprabhu L. Patil.

Contents

Foreword v

Preface vii

1 Mechanisms of Virus Resistance in Plants 1
M. E. Chrissie Rey and Vincent N. Fondong

2 Role of Host Transcription Factors in Modulating Defense Response During Plant–Virus Interaction 25
Saurabh Pandey, Pranav P. Sahu, Ritika Kulshreshtha and Manoj Prasad

3 Surfacing the Role of Epigenetics in Host–Virus Interaction 55
Namisha Sharma, Pranav P. Sahu, Ritika Kulshreshtha and Manoj Prasad

4 Molecular Markers as Tools for Identification and Introgression of Virus-Resistant Genes 87
Mamta Sharma, Avijit Tarafdar, U. S. Sharath Chandran, Devashish R. Chobe and Raju Ghosh

5 Genetic Engineering for Virus Resistance in Plants: Principles and Methods 103
Basavaprabhu L. Patil

6 Tools and Techniques for Production of Double-stranded RNA and its Application for Management of Plant Viral Diseases 119
Andreas E. Voloudakis, Maria C. Holeva, Athanasios Kaldis and Dongho Kim

7 Transgenic Virus-Resistant Papaya: Current Status and Future Trends 141
Gustavo Fermin, Paula Tennant and Sudeshna Mazumdar-Leighton

8 Development and Delivery of Transgenic Virus-resistant Cassava in East Africa 159
Henry Wagaba, Andrew Kiggundu and Nigel Taylor

9 Viruses Infecting Rice and their Transgenic Control 177
Gaurav Kumar, Shweta Sharma and Indranil Dasgupta

10 Whitefly-transmitted Begomoviruses and Advances in the Control of their Vectors 201
Surapathrudu Kanakala and Murad Ghanim

11 Virus-resistant Transgenic Tomato: Current Status and Future Prospects 221
S.V. Ramesh and Shelly Praveen

12 Management of Geminiviruses Focusing on Small RNAs in Tomato 235
Archana Singh and Sunil Kumar Mukherjee

13 Viruses Infecting Banana and their Transgenic Management 255
Ramasamy Selvarajan, Chelliah Anuradha, Velusamy Balasubramanian, Sivalingam Elayabalan and Kanicheluam Prasanya Selvam

14 Virus-induced Gene Silencing (VIGS) and its Applications 277
Deep Ratan Kumar, Tejbhan Saini and Radhamani Anandalakshmi

15 Possible Strategies for Establishment of VIGS Protocol in Chickpea 329
Ranjita Sinha and Muthappa Senthil-Kumar

Index 345

Foreword

In 1986, the first report on the use of genetic engineering to control *Tobacco mosaic virus* in tobacco plants was published and it opened the gate to a flood of publications for the possible control of many viruses in many hosts. At that time, this concept of engineering virus resistance was a breakthrough. Controlling plant viruses has always been a big challenge to breeders, and suddenly it was possible to control almost any virus in any crop through genetic engineering! Evidently, over the years many natural sources of resistance for numerous plant viruses had been identified; however, combining these resistance sources with other traits was always a challenge to breeders. Therefore, genetic engineering appeared as *the* solution to control plant viruses!

But three decades later, we have to acknowledge that we have not seen the expected revolution in farmers' fields. On the contrary, we have seen the emergence and outbreak of many new and known plant viral diseases, threatening food security. Even though some plants have been engineered with multiple virus resistance, they have never been commercialized. The engineered papaya with immunity to *Papaya ringspot virus* remains the most successful example of commercialization of virus-resistant transgenics.

The failure to commercialize virus-resistant transgenics is the result not of technical or scientific problems or any sort of biological barrier, but mostly of political pressures from so-called ecological groups. In the meantime, improved technologies were developed and transferred to new crops and novel viruses, and in some instances made real scientific breakthroughs. However, the vested interests of these groups of fanatics, with a false claim of saving the earth's ecology, raised biosafety standards to the point where only large multinationals could afford them, which de facto prevented the application of these technologies to many important food crops in the world.

In the beginning of the twenty-first century, the genomic revolution brought new hopes to control plant viruses by harnessing natural genes of resistance. Whole-genome sequencing of many plants, along with scores of novel DNA technologies, facilitated the use of modern tools in gene discovery for virus resistance. However, the introgression of these resistant loci was restricted due to their multigenic or recessive nature, making it difficult to transfer them to a suitable genetic background without using genetic engineering technologies.

Recently, the discovery and use of gene-editing technologies such as CRISPR/Cas9 and TALENs may now allow plant virologists, genomics experts and breeders to work together for a breakthrough in controlling plant viruses. This can be a reality only if these technologies are not considered to be GM- technologies by policy makers.

This book, *Genes, Genetics and Transgenics for Virus Resistance in Plants*, provides a very nice update on the status of current knowledge on the use of genetic engineering and other biotechnological strategies for the control of plant viruses. It is hoped that this information will be used in conjunction with the latest gene technologies to achieve the urgently needed scientific breakthroughs for the successful control of plant viruses, ultimately for the benefit of humankind.

Claude M. Fauquet
Director, Global Cassava Partnership for the 21st Century (GCP-21)
International Center for Tropical Agriculture (CIAT), Cali, Colombia

Preface

Viral diseases of crop plants cause significant yield losses, which is a major threat to global food security. Unlike other pests and pathogens, the only remedy available for control of plant viral diseases is through introgression of resistance trait, either through conventional breeding or through genetic engineering. Availability of few natural sources of virus resistance has hampered development of virus-resistant crop plants through conventional crop improvement methods. Thus genetic engineering for virus resistance is the sole option available for effective management of viral diseases. Since the first report on transgenic virus resistance in tobacco in 1986, huge progress has been made in our understanding of the molecular basis of virus resistance, complimented by the significant improvement in the tools and techniques used for genetic engineering. Despite major advancements in plant genomics and transgenics, there has been no commercialization of virus-resistant transgenic crops, except transgenic papaya. Thus, to provide an up-to-date reference book on genes, genetics and transgenics for virus resistance in plants for students, faculties and researchers, here we have compiled 15 diverse chapters. In the first chapter the current knowledge on mechanisms of virus resistance in plants is discussed, followed by a chapter on the role of host transcription factors in modulating defence response during plant-virus interaction, and a chapter on the role of epigenetics in host-virus interactions. There is a chapter on how molecular markers could be employed as tools for identification and introgression of virus-resistant genes. This book also thoroughly discusses the principles and methods involved in the genetic engineering for virus resistance in plants. The book also elaborates on topical application of double-stranded RNA for control of plant viral diseases, without having to develop transgenic plants. Further, the book deals with individual crops such as papaya, cassava, rice, tomato, and banana, for which virus resistance has been accomplished by employing different transgenic technologies. The management of whitefly-transmitted begomoviruses and advances in the control of their vectors is also covered as an independent chapter. Virus-induced gene silencing (VIGS), another frontier area of research in which virus-derived silencing vectors are extensively used in gene function studies and functional genomics, is also discussed elaborately.

5. Genetic engineering for virus resistance in plants: principles and methods. Basavaprabhu L. Patil. Pages: 103-118.Â DsRNA-mediated resistance has been exploited in transgenic plants to convey resistance against viruses and against insects, vectors of plant viruses, via host induced gene silencing (HIGS). A non-transgenic approach employing RNAi has been used where enzymatically synthesized specific dsRNA molecules, when applied directly onto plant tissue, induce resistance against the cognate virus; as a result dsRNA molecules could be efficacious antiviral agents for crop protection. Next generation sequencing and bioinformatics analyses have provided a plethora of information and useful tools for the desi Researchers have long observed that transgenic plants expressing genes derived from viral pathogens often display immunity to the pathogen and its related strains (Lomonossoff, 1995). These results led to the hypothesis that ectopic expression of genes encoding wild-type or mutant viral proteins could interfere with the viral life cycle (Sanford and Johnston, 1985).Â Most plant viruses contain single-stranded RNA as their genetic information. Double-stranded RNA (dsRNA) replicative intermediates often form during the replication of the viral genome mediated by RNA-dependent RNA polymerase, triggering RNAi in the host.Â CRISPR-Cas platforms for engineering viral resistance in plants. Plant viruses complete their life cycles in the host cells.