Genes, Genetics and Transgenics for Virus Resistance in Plants

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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.

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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.

Virus Gene. Viral genes are introduced into bacteria, yeast, plants, or cultured cells where the desired protein is produced. From: Viruses, 2017. Related termsÂ H.V. Davies, in Developments in Plant Genetics and Breeding, 2000. Viruses. Viral genes: Whilst the search for the identity of new sources of resistance continues to be a major challenge, the success of genetic engineering for virus resistance must still represent one of the major success stories in plant biotechnology (Davies 1996 and references therein). New sources of antiviral transgenes that give resistance continue to be discovered. One of the best-documented approaches is coat protein (CP)-mediated resistance, now widely effective against PVX, PVY, PLRV and mop top. Plant viruses are superb entities for the elucidation of hostâ€"microbe interactions as they encode relatively few proteins and are exclusively dependent on host cellular metabolism for multiplication and movement.Â Classically, HR-mediated resistance is known to be triggered when a pathogen-encoded avirulence factor (Avr) is recognized in plants by a host R gene product (Albar et al., 2006; Moffett, 2009). According to current plant immunity descriptions, there are two layers of plant immune responses against microbial pathogens. In conventional transgenic methods, genes that encode desired agronomic traits are inserted into the genome at random locations through plant transformation (Lorence and Verpoorte, 2004). These methods typically result in varieties containing foreign DNA. In contrast, genome editing allows changes to the endogenous plant DNA, such as deletions, insertions, and replacements of DNA of various lengths at designated targets (Barrangou and Doudna, 2016).Â CRISPR-Cas platforms for engineering viral resistance in plants. Plant viruses complete their life cycles in the host cells. Viral particles with geminate capsids, and rod-shaped capsids are used as examples to illustrate DNA viruses and RNA viruses, respectively. Proteinase inhibitor genes from mammals have also been transferred and expressed in plants to provide resistance against insects, although the success in this direction is very limited. Bovine pancreatic trypsin inhibitor (BPTI) and Î±1â€" antitrypsin genes appear to be promising to offer insect resistance to transgenic plants. Insect Resistance through Copy Nature StrategyÂ A selected list of the virus resistant transgenic plants with sources of virus coat protein genes is given in Table 50.4. The transgenic plant providing coat protein-mediated resistance to virus are rice, potato, wheat, tobacco, peanut, sugar beet, alfalfa etc. Plants have evolved R genes (resistance genes) whose products mediate resistance to specific virus, bacteria, oomycete, fungus, nematode or insect strains. R gene products are proteins that allow recognition of specific pathogen effectors, either through direct binding or by recognition of the effector's alteration of a host protein.[6] Many R genes encode NB-LRR proteins (proteins with nucleotide-binding and leucine-rich repeat domains, also known as NLR proteins or STAND proteins, among other names).Â Transgenic plant disease resistance against microbial pathogens was first demonstrated in 1986. Expression of viral coat protein gene sequences conferred virus resistance via small RNAs.