# Gene-for-Gene Interactions Are Required for Disease Resistance Mediated by Virus Transgene

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**Abstract**

Plant viruses cause severe damage and significant economic losses to agriculture. Control of virus usually consist of the elimination of virus vectors (insects, nematodes, fungi, etc), improvement of the sanitary status of the propagation material, the use of resistance sources in breeding programs. The application of the pathogen-derived resistance strategy has opened new avenues to protect plants against viruses. Two molecular mechanisms seem to underlie the engineered protection, the virus transgene-derived protein and the transgene-RNA interference. A few examples that support the efficiencies of these two molecular mechanisms are reviewed here and discussed in light of the potential use of virus-resistant transgenic plants in agriculture.

**Keywords**: virus; transgenics; resistance; agriculture

## INTRODUCTION

Plant pathologists and breeders are developing strategies to control virus diseases. Understanding the biological properties of viruses and virus transmission process is an important prerequisite that complement the identification and use of host resistance sources.

MC KINNEY (1929) used cross protection to control *Tobacco mosaic virus* (TMV) by the use of a mild strain to protect plants against infection by a severe strain. GONSALVES and GARNSEY (1989), LECOQ *et al*. (1991), GAL-ON and RACCAH (2000) reviewed the practical use of cross protection to control virus diseases.

BEACHY *et al*. (1986) have shown that the introduction of a virus gene encoding a capsid protein (CP) into a plant genome can protect against the homologous virus. In the 90's, information was gained on the molecular mechanisms of the engineered protection. Subsequently, it became clear that a certain degree of specificity existed between the virus-derived transgene and the incoming virus, indicating the occurrence of a sequence homology-dependent mechanism. This report reviews the use of transgenic plants containing CP transgenes (transcripts or proteins) that can interfere with virus replication, long distance transport or subunit disassembly.

## RESULTS AND DISCUSSION

### Coat-protein gene-derived resistance

Since the discovery of POWELL-ABEL *et al*. (1986) numerous transgenic plants have been produced. Two basic molecular mechanisms are involved: the coat protein- and RNA-mediated resistance (Figure 1).

### Subunit of capsid protein for protection

Using TMV as model, it has been demonstrated that the CP subunits engineered in transgenic plants of CP are capable to induce a delay in virus symptom development (POWELL-ABEL *et al*. 1986). Such findings are explained by interference with the initial phase of TMV disassembly that occur in early events of infection (REGISTER & BEACHY 1988). BENDHAMANE *et al*. (1997) demonstrated that the stability of the CP produced by the genetically modified plants,

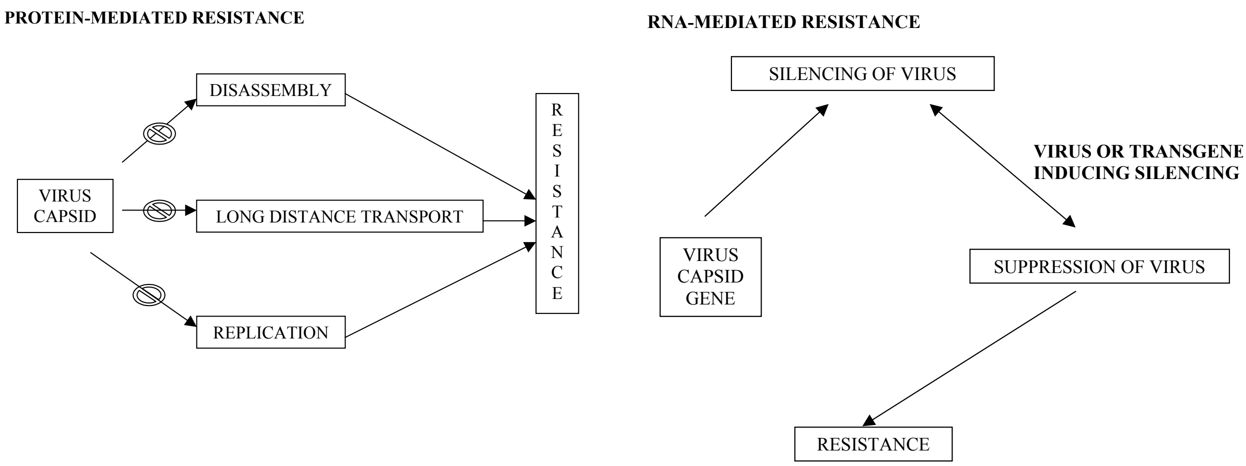


Figure 1. Schematic diagram summarizing the two molecular mechanisms induced by the introduction of virus capsid gene in plant genome

in particular three couples of key aminoacids located at the NH2 end of the CP, is critical for the level of resistance.

### Nucleotide sequence of capsid gene for conferring protection

DOUGHERTY and PARKS (1995), BAULCOMBE (1996) demonstrated the phenomenon of RNA-mediated resistance. These authors showed that resistance could be achieved in transgenic plants containing the CP gene and expressing CP gene transcripts but not the CP. The production of CP transcripts and its degradation independently or associated with the RNAs of the challenge virus led to the discovery of post-transcriptional gene silencing (PTGS). PTGS specifically targets the virus-derived transgene sequence as well the homologous sequence from the challenge virus. A few economically important crops expressing CP gene transcripts but not the CP have potential for future use in agriculture (GONSALVES 1998; PANG *et al*. 2000; SCORZA *et al*. 2001)

## Applicability in agriculture

### Benefits

Transgenic squash designated as "Freedom II" is among the first virus-resistant crop that was deregulated and commercially released in the USA. It contains the *Zucchini yellow mosaic virus* (ZYMV) and *Watermelon mosaic virus* (WMV) CP genes and is resistant to single and mixed virus infection by ZYMV and/or WMV. Transgenic papaya resistant to *Papaya ringspot virus* (PRSV) was recently deregulated (GONSALVES 1998). This technology applied to control viruses of fruit trees (RAVELONANDRO *et al*. 2000) and vegetables (PANG *et al*. 2000; THOMAS *et al*. 1997) increase not only yield but also contribute to the reduced use or even elimination of chemicals to control aphid vectors (PHILIPPS & PARK 2002). A few virus-resistant transgenic plants have been deregulated in the USA (Table 1).

### Environmental safety issues

The use of virus-resistant transgenic plants raised concerns for their release into the environnment. Transencapsidation (LECOQ *et al*. 1993) and recombination (FUCHS *et al*. 2001) can conduct to the emergence of new viruses. Many studies have been achieved under greenhouse conditions or in a restricted field area. Interestingly, no detrimental effects beyond those of natural background events have been observed so far.

The USDA, EPA, and FDA have deregulated transgenic potato, squash and papaya in the USA. These

Table 1. Deregulated crops engineered with phytovirus transgene

| Virus transgene | Crops | Year |
|---|---|---|
| WMV2 & ZYMV CP | Squash | 1994 |
| CMV, ZYMV WMV2 CP | Squash | 1997 |
| PRSV CP | Papaya | 1998 |
| PLRV CP & replicase | Potato | 1999 |
| PVY CP | Potato | 1999 |

decisions were based on scientific risk impact studies. No labelling of the final products to be used by consumers is required in North America. Contrary, the European Union requires this information by law (Official Journal of the European Communities 2000). Such controversy is compromising the acceptance of the biotechnology products in Europe. Benefits from biotechnology must be shared and not be restricted only to the New World because such atmosphere would lead to a technological clash between the two continents.

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