Plant Biotechnology: 
Current and Potential Impact 
For Improving Pest Management 
In U.S. Agriculture 
An Analysis of 40 Case Studies 
June 2002

Viral Resistant Stone Fruit

Leonard P. Gianessi 
Cressida S. Silvers 
Sujatha Sankula 
Janet E. Carpenter

National Center for Food and Agricultural Policy 
1616 P Street, NW 
Washington, DC 20036 
Phone: (202) 328-5048 
Fax: (202) 328-5133 
E-mail: ncfap@ncfap.org 
Website: www.ncfap.org

Financial Support for this study was provided by the Rockefeller Foundation, Monsanto, The Biotechnology Industry Organization, The Council for Biotechnology Information, The Grocery Manufacturers of America and CropLife America.
15. STONE FRUIT

Viral Resistant

Production
In 2000, there were 5,500 bearing peach tree acres in Pennsylvania. Total production was 60 million pounds valued at $17 million [1]. In addition to peaches, Pennsylvania orchardists maintain 868 acres of other stone fruits: 669 acres of nectarines, 160 acres of plums, and 39 acres of apricots [2]. Approximately one-half of Pennsylvania’s peach tree acreage is located in Adams County on the southern border with Maryland [2].

Plum Pox Virus
In the summer of 1999, Adams County was the location of the first detection of plum pox virus in North America [17]. Plum pox virus (PPV), also widely known by its Bulgarian name, sharka, is a devastating disease of stone fruits, including plums, peaches, nectarines and apricots. It causes significant economic losses and is a limiting factor in stone fruit production in regions where it is found, including in several European countries. The disease first was reported in 1915 in Bulgaria and reached Yugoslavia in 1935 and Hungary about 1941. It spread more rapidly after 1950, reaching Germany in 1956, Poland and Romania in 1961, and France in 1970. The disease was eradicated in England in the 1960’s only to reappear in the early 1970’s. In 1984, Spain was invaded by plum pox [9]. Altogether, it has been estimated that over 100 million European trees are infected. Reported annual losses in Bulgaria have been as high as 60,000 tons of fruit. Reported yield losses in Poland have been greater than 50% and in Czechoslovakia they have averaged as high as 83.4% [4]. In Chile, plum pox symptoms first were detected in 1992. Fifteen percent of Chile’s stone fruit acreage is infected.

Growers in Europe have learned to live with the disease [10]. The spread of plum pox is reduced by planting only certified disease-free plants, maintaining tight aphid spray programs and eliminating weeds that can be infected with the virus. A major control method is to remove trees showing symptoms immediately. In some cases, whole orchards have been removed [10].

As a result of the discovery of PPV in Adams County, PA, the Pennsylvania Agriculture Department established a quarantine of the affected areas. Canada immediately suspended all
import permits for plant material from the entire U.S. [3, 5], but has recently limited the ban to imports from Pennsylvania [6]. The Pennsylvania quarantine prohibits the movement of susceptible trees and propagative material within and out of the quarantine area. In March of 2000, the U.S. Secretary of Agriculture declared that PPV presented an emergency that threatened the nation’s $2 billion stone fruit industry, and authorized the use of available funds for control and prevention of PPV spread, and eradication of PPV where it exists in the U.S. [7]. The USDA concluded that if steps were not taken to eradicate plum pox in Pennsylvania there was every possibility that the disease eventually would spread to other areas in the U.S. [7]. Therefore the USDA established: (1) a regulatory program to prevent the movement of plant material within or out of quarantine areas in Pennsylvania; (2) a survey program to detect any additional infections; and (3) a control program to remove all infected orchards [7]. In January of 2001, the Pennsylvania Agriculture Department declared a moratorium on planting PPV-susceptible trees or shrubs in the PPV quarantine zones [8]. To date, the state has invested an estimated $5.1 million in PPV eradication and farmer indemnity, and approximately 1350 commercial acres of infected and exposed trees have been destroyed.

The Commonwealth of Pennsylvania has agreed to pay $1,000 an acre to growers to cover the cost of removing trees. Federal agencies approved a measure of $18 million to compensate growers for losses from plum pox, and the Pennsylvania Legislature approved $3 million in compensation.

Plum pox virus produces symptoms such as leaf discoloration and rings or spots on fruit [9]. Symptoms vary with host cultivar, plums being most severely affected. Symptoms include premature fruit drop, deformed fruit, and discoloration of the skin and flesh. Regardless of how severe leaf and fruit symptoms are, trees infected with plum pox will suffer from decreased production and reduced fruit quality with crop losses as high as 80 to 100% [3]. Much of the infected fruit drops prematurely, 20 to 30 days before normal maturity date. The fruit that remain on the trees lacks flavor and is low in sugar content. The virus so seriously affects the fruit of diseased trees that the fruit become unsuitable for direct consumption or industrial processing (dried, jams or brandied). Plum pox does not kill trees, but it makes the fruit unmarketable and drastically reduces yields.
Plum pox virus is spread over short distances, such as within and between orchards, by aphids. In Pennsylvania, one of the most efficient vectors is the green peach aphid. Aphids transmit PPV in a nonpersistent manner, which means uptake of the virus by the aphid and transmission to another plant occur within a few minutes.

The virus can occur in high concentrations in leaf cells, and when an aphid probes into an infected cell, some of the virus is sucked into the aphid’s mouth parts, where it can stick to the lining of the food canal and remain infectious there for several minutes or hours. If the aphid then feeds on a healthy plant and continues to probe into a healthy epidermal cell, the virus carried in the food canal can detach and be squirted back into the healthy plant cell [9]. Research has determined that there are roughly 3.5 million aphids in a typical planted orchard acre, and between 50,000 and 300,000 aphids from that acre can visit a fruit tree in a one year period [3].

Long distance spread of PPV between geographic regions, and the method by which it is introduced into an area, is through transport of infected plants or plant parts, such as buds for grafting, by humans.

There is no treatment to cure virus infected trees, and once a tree is infected it serves as a source for infection of other trees. Identification, speedy removal and destruction of infected and potentially exposed trees is the only method of preventing increased spread of the virus. Combined with quarantine efforts to prevent renewed introduction of virus infected plant material to the area, these practices aim to at least contain, and at best eradicate, PPV infestations.

Detection of PPV, and the subsequent removal of trees, is expensive. The cost of tree removal and destruction is estimated at $1,500 per acre [10]. With 1350 acres already removed, well over $1 million has been spent in removal alone. In addition to this and the cost of replanting, the grower has to wait six years before replanted trees reach full production. The USDA mandates that once an orchard has been removed due to PPV infection, it cannot be replanted to PPV susceptible plants for three years. Growers can not replant susceptible prunus until the
quarantine is lifted – the quarantine will not be lifted until three years of no new positive finds in
the survey [18]. The average annual value of an acre of mature stone fruit in Adams County is
$1,038. For fruit growers in Pennsylvania, the only alternative to stone fruit is apple. But the
profit margin on apples is lower than that for peaches, and with the area already so inundated
with apple orchards, flooding the market with more would further reduce prices [3, 10].

Control of aphid populations with insecticides may reduce their levels, but because it takes only
one aphid a few seconds to transmit PPV from an infected tree to a healthy one, insecticide
applications will not effectively control PPV infestations. In the case of PPV, control through
aphid management would be particularly difficult because there are several species of aphids that
may transmit the virus. Scouting and treating for PPV-transmitting aphids would be necessary
throughout the year, costing growers in time, labor and materials for a control strategy that is not
adequately effective.

If eradication efforts are not successful in Pennsylvania, PPV threatens to spread to and devastate
stone fruit production throughout North America. It has already been detected in Canada, and
monitoring and grower education efforts are underway in other stone fruit production areas such
as California [11]. The next line of defense is to plant varieties with resistance to PPV. Trees
with PPV tolerance, although suffering few symptoms themselves, would still allow the virus to
survive and replicate, serving as a source for continued spread. Only trees with resistance or
immunity, whereby the virus cannot survive in the plant, will avoid losses and reduce incidences
of PPV.

**Viral Resistant Stone Fruit**

For more than 50 years, classical plant breeding produced few stone fruit varieties that are highly
resistant to PPV [14]. There are few sources for PPV resistance in stone fruit. Those that have
been identified are controlled by multiple genes and are therefore very difficult to breed into new
varieties.

The most recent progress in developing resistance to PPV has involved genetic engineering of
resistant stone fruit species [9].
USDA ARS researchers in West Virginia, collaborating with researchers in Europe, have had success in engineering a transgenic plum variety with resistance to PPV [12]. Using Agrobacterium, they inserted viral coat protein genes into plum cells. The aim was to achieve coat protein mediated resistance, in which the ability of the plant cell to produce the viral coat protein somehow prevents invading viroids from uncoating, and thereby prevents them from replicating and spreading within the plant. Usually when this procedure is successful, high levels of viral coat genes and proteins are detected in the transformed plants. In one of the transformed plum lines, there was little detection of viral genetic material and no detection of viral or transgenic coat proteins. This transgenic plum line, C-5, exhibited excellent resistance to PPV whether inoculated through aphids or grafting using PPV infected budwood.

In greenhouse trials in which C-5 plum trees were exposed to aphids infected with PPV, and grafted with infected bud wood, the transgenic trees remained virus free for three years. In contrast, 30% of the non-transgenic trees in the experiment showed symptoms of the virus infection after six months, 67% showed symptoms after 12 months and 100% showed symptoms after 3 years [12].

The lack of viral protein in C-5 plants, and other characteristics, including the finding that the viral transgene insertion resulted in a complex transgene with multiple and aberrant gene copies, led researchers to conclude that the mechanism of PPV resistance in C-5 plums is due to post transcriptional gene silencing (PTGS), whereby the plant cell recognizes and shuts off invading viral genes, before they produce any proteins [13, 14]. Production of transgenic coat protein by the plant is also eliminated by PTGS.

The C-5 cultivar was produced using a new, commercially viable plum variety called ‘Bluebyrd’, which has excellent fruit quality as the female parent [16]. In addition, PPV resistance exhibited by C-5 transgenic plums is inherited in seed as a single gene, and is therefore available to incorporate into traditional plum breeding programs for future production of new varieties [14]. Ongoing work includes investigating the possibility of resistance expression in vegetative plant parts only so that the edible fruit will not be transgenic. Research also continues on developing a
successful transformation system for peaches, which so far has been elusive, so that the PPV resistance developed in C-5 plums can be incorporated into peach varieties [15].

The transgenic plum plants currently are restricted to laboratories in the U.S. Although the transgenic plum was developed in laboratories in the U.S., the trees are not being inoculated in the outdoors in the U.S. because of concerns about releasing the plum pox virus into the environment. Rather, the trees are being tested in orchard settings in Spain, France, Romania and Poland, where the virus is prevalent.

**Estimated Impacts**

It is assumed that a transgenic viral resistant stone fruit cultivar could be planted universally in Pennsylvania and would prevent the complete loss of production in the state (60 million pounds with a value of $17 million).
References


