

Plum Pox Virus of Stone Fruits

Disease History and Distribution

The disease referred to as plum pox was first reported in 1915 in Bulgarian plums. Sharka is the Slavic name for plum pox and is the most widely used common name for the disease around the world. At first, the disease spread rather slowly northward through eastern Europe, reaching the former Yugoslavia in 1935 and Hungary about 1941. It spread more rapidly after about 1950, reaching Germany in 1956, Poland and Russia in 1961, and France in 1970. In 1984, Spain became the most recent western European country to be invaded by plum pox.

Throughout Europe, plum pox is considered the most devastating disease of stone fruits. It has been estimated that over 100 million European trees are infected. Plum pox continues to spread eastward in Eurasia and southward along the Mediterranean coast of Africa. In 1992, plum pox symptoms were first detected in the Western Hemisphere, in Chile.

At this time, the only identified occurrence of plum pox in North America is localized in a small number of orchards in Adams County, Pennsylvania. Because of the localized nature of this infection, it is hoped that eradication may be successful in eliminating this pocket of PPV in North America.

Susceptible Plants

Plum pox disease is caused by a virus. Plant viruses are named according to the plant host in which they are first identified, hence the name plum pox virus or PPV. PPV infects not only plum but also all other economically important cultivated

stone fruit species including peach, nectarine, apricot, almond, and cherry. PPV is also known to have the ability to infect wild *Prunus* (stone fruit) species and a very large number of wild native and introduced weed species.

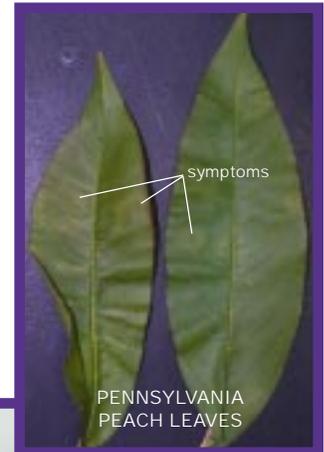
VARIETY SUSCEPTIBILITY

In Europe, it appears that some varieties are more susceptible than others, but the literature is often contradictory. For example, a single variety might be listed as both "resistant" and "highly susceptible" by different authors and for different regions. Given this caution, some general statements can be made about variety susceptibility. In France, natural infection can occur in peach, apricot, plum, and Japanese plum. Almond, sweet cherry, and sour cherry are not naturally infected in France but can be artificially infected by the PPV-D strain. Japanese plum appears to be highly susceptible to PPV.

Symptoms

It is important to note that PPV will be economically important even on symptomless cultivars that become infected but fail to produce severe or obvious symptoms. PPV infection of fruit trees not only causes diagnostic symptoms on leaves and fruits,

but also reduces total quantities of even symptomless fruits. In addition, it reduces fruit quality,



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resulting in reductions in grade, and eventually debilitates the tree, reducing its useful life.

PPV symptoms in stone fruits may vary considerably with the cultivar, age and nutrient status of the plant, and the temperature. Also, different strains of PPV may vary in the severity of the disease they cause and the resulting symptoms. The virus often can be detected at the bottom of a branch but not the tip. Finally, not every leaf or fruit on an infected tree will show symptoms.

Diagnostic symptoms on leaves may consist of mild light green discoloration bordering the leaf veins (vein yellowing)

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or yellow to light green rings. These symptoms may be only barely visible to the eye, depending on factors described above.

Flower symptoms can occur on varieties with showy peach blossoms, but do not always occur. Flower symptoms are common in France, but evidently not in Spain. Peach and apricot fruit may develop lightly pigmented yellow rings or line patterns resulting from several rings running together on the surface of the fruit. Fruit may become deformed or irregular in shape and develop necrotic or brown dead areas. Apricot fruit may show no external evidence of disease, but may have white ring or line patterns on the seed.

Plums generally are more severely affected and show more severe symptoms than other stone fruits. Therefore, they are a good indicator host to observe for symptoms of infection, allowing growers to monitor for

PPV in orchards. For some plum cultivars, infected fruit drops prematurely from the tree. Infected plum fruits often are severely deformed and develop darker rings or spots on the skin and a reddish discoloration of the flesh. In Hungary, green shoot cankers can be observed in the fall on infected plums. The cankers are brown with purple borders.

Unfortunately, many trees fail to show symptoms for the first three years following the initial infection of the tree. In France, for example, the virus can be detected using laboratory tests the year after infection occurs; however, leaf or fruit symptoms do not generally appear until the third year. Serological tests performed in the laboratory can detect PPV even before visual symptoms develop. Serological surveys to detect PPV in Pennsylvania orchards, directed by Ruth Welliver at the Pennsylvania Department of Agriculture

in October of 1999, detected 18 infected orchards, but only 2 of the 18 had trees showing obvious symptoms. A lack of symptoms, therefore, is not a good indicator that the orchard is healthy. Symptoms alone cannot be relied upon to determine the incidence or range of the disease. When symptoms do occur, however, they frequently indicate the presence of PPV.

The first person to identify the symptoms of PPV in Pennsylvania peach orchards was a grower, and growers have the opportunity to see more trees over a longer period of time than anyone else. Thus the role of growers, extension agents, and home owners in identifying stone fruit trees with PPV symptoms is

important to the total eradication of the disease from the state. The continual vigilance of stone fruit growers will supplement the serological surveys conducted by the P.D.A. No serological survey tests every tree in the orchard, so the possibility always exists that an infected tree or small orchard has been missed. A grower

who identifies a potentially infected stone fruit tree should contact the local county extension office to have the tree serologically tested for PPV.

Characteristics of Plum Pox Virus

Plum pox virus is known to occur in several different forms or variants, called strains. At this time, four distinct major strains have been identified and designated as PPV-D, PPV-M, PPV-C, and PPV-EA. These strains can be distinguished using laboratory tests. The most common European strains reported are PPV-D and PPV-M. These two strains differ in symptom severity among host species and in patterns of spread by aphids. PPV-D was the strain that was recently discovered in Pennsylvania. This may be fortunate,

because PPV-D is not known to be readily seed transmitted and seems to be more slowly spread by aphids in Europe than PPV-M, thus giving more hope of successful eradication if infected trees are quickly detected and destroyed.

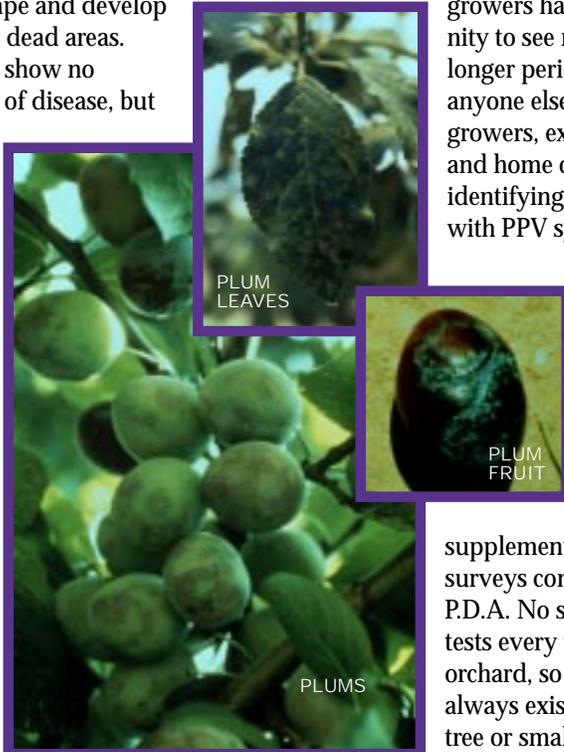
Mechanisms for PPV Transmission and Spread

SHORT-DISTANCE SPREAD IN AND BETWEEN ORCHARDS

In natural settings such as orchards, PPV is spread over short distances only by aphids. Aphids are small insects that feed through modified piercing-sucking mouthparts on internal vascular tissues of plants. Because PPV has not previously occurred in the U.S., no studies have been done to determine which aphid species in Pennsylvania orchards are capable of transmitting PPV; however, several aphid vector species occur in the fruit growing region of southeastern Pennsylvania where PPV has been identified. One of the most efficient vectors, the green peach aphid (*Myzus persicae*), colonizes peaches and other stone fruits in Pennsylvania. Therefore, the potential exists for aphid spread of PPV in Pennsylvania. The distribution of infected Pennsylvania orchards identified in 1999 is consistent with aphid spread.

The mechanism by which aphids transmit PPV is called nonpersistent transmission. This refers to the fact that once the aphid probes into an infected plant and acquires the virus, the virus remains infectious and can be transmitted by the aphid only for a short time (a matter of minutes). Aphids make two kinds of probes on leaf surfaces, test probes and feeding probes. Rapid transmission of PPV occurs specifically during aphid test probes and not during the longer-lasting feeding probes.

The virus can occur in high concentrations in leaf cells, and when the aphid test probes into an infected cell, some of the virus is sucked into the stylet where it can stick to the lining of the food canal in the center of the stylet and remain infectious there for several minutes or hours. If the aphid then flies to a healthy plant and initiates a test probe into a healthy epidermal cell, the virus carried on the food canal can detach and be squirted back into the healthy plant cell when the aphid expels the contents of the food canal before sucking up fresh cell contents for taste



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testing. It is during this process that the virus is transmitted.

In addition, transmissible virus that has been picked up by an aphid is lost during the next test probe; therefore, aphids feeding on an infected cell can transmit that virus only to the next cell on which they feed. Each aphid must feed directly on an infected plant, acquire sufficient virus, and then fly immediately to the next plant to effect a transmission. In many cases, aphids are thought to spread PPV from leaf to leaf or branch to branch while test probing on a single tree, resulting in multiple infection sites on one tree. PPV does not increase in the aphid and does not circulate in the aphid's body.

Finally, the efficiency of PPV transmission or rate of virus spread from apricot to peach, from peach to peach, and from plum to peach may all differ.

LONG-DISTANCE SPREAD BETWEEN ORCHARDS OR GEOGRAPHICAL REGIONS

Long-distance spread of PPV and the introduction of the virus to new regions where it previously has not been known to exist occurs primarily by movement of infected plants or plant parts by human activity. Discovery of PPV in several European countries has been associated with introductions of infected nursery stock from other countries. Buds taken from infected trees will carry the virus and transfer it when grafted to healthy trees.

Long-distance spread by flying aphids is unlikely even in continuous land areas, because aphids lose nonpersistently transmitted viruses when they probe on any non-host species. Also, PPV becomes noninfectious in the aphid usually within an hour after acquisition.

THE ROLE OF WEEDS

One aspect of PPV spread that is poorly understood is the potential role of native plants or weeds in PPV survival and spread. Laboratory tests in Europe have identified several dozen common plants or weeds that can be mechanically inoculated with PPV. Whether or not weeds could play a significant role in PPV survival and spread between orchards in Pennsylvania has not yet been determined. No current evidence suggests that weeds play an important role in PPV spread.

Control: Exclusion and Quarantine

Once PPV becomes established in a geographical region, it is very difficult or impossible to completely eradicate. Therefore, the primary focus is placed on preventing the introduction of PPV to new fruit-growing areas. In the United States, this is the responsibility of the Animal and Plant Health Inspection Service (APHIS) of the U.S.D.A. All fruit nursery stock for importation is tested for a range of known fruit tree pathogens, especially those that are not known to occur in the United States ("exotic" pathogens). Only pathogen-free material is released for commercial use.

The localized occurrence of PPV in Pennsylvania serves to remind everyone of the importance of and need for strict plant

quarantine and testing procedures associated with imported nursery materials. In almost all cases, intercontinental spread of plant disease causal agents is associated with human transfer of infected host materials. Therefore, once the diseases have been eliminated, careful regulation and inspection combined with education of

importers and travelers could prevent the reintroduction of exotic plant diseases from threatening U.S. crops.

Quarantine also can be effective in preventing long-distance spread of PPV within a region, state, or country. If the disease occurs only in a small area, it may be contained by local quarantines preventing movement of infected materials out of that area. Such a quarantine was implemented on October 21, 1999 for Huntington and Latimore townships in Adams County, Pennsylvania, by the Pennsylvania Department of Agriculture. If it was implemented before the movement of infected materials occurred, this quarantine will be effective in preventing the spread of PPV.

The second strategy for preventing virus introduction into to a new area is for commercial growers and nursery propaga-

tors to purchase only certified virus-free planting stock that has been tested and verified to be free of PPV and other fruit viruses. In the future, it will be important for growers to verify that certified stone fruit nursery stock, from any source, also has been tested for PPV.

Control: Eradication

If preventive measures fail to exclude PPV from a growing area, the next control strategy is to eliminate the virus-infected trees as quickly as possible before the virus spreads. Virus-infected trees cannot be cured, and the virus cannot be eliminated from individual trees. Therefore, it is necessary to destroy PPV-infected trees once they have been identified. A single infected tree in an orchard would serve as a virus source for all surrounding trees and for closely adjacent orchards.

Once PPV is detected in a new region, intensive surveys must be taken to identify the extent of its spread. How samples are collected from individual trees or from orchards is important in determining the statistical reliability of the test results in verifying the absence of PPV from an area. For example, although PPV can infect all tree tissues, it generally is not evenly distributed throughout the tree. Some branches, leaves, flowers, or fruits of infected trees may contain detectable levels of virus, while other parts of the tree may appear uninfected because of either low virus concentrations or absence of virus in that tissue. This becomes an important consideration when sampling individual trees for laboratory testing; samples should be collected and tested from multiple sites around the tree.

Once infected trees have been identified, the cure is simple and is administered with a bulldozer, chain saw, or other tree-removal equipment. Rapidly growing sucker shoots developing from infected roots are known to be a good source of PPV, so they must be monitored and eradicated as well.

IDENTIFYING AND ELIMINATING INFECTED ORCHARDS IN EUROPE

Most newly infected orchards are detected up to about 200 yards away from an infected site, but some can be found up to 1,000 yards away from infected trees. The infections in the second season after an orchard has been determined to be



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infected are widely scattered from the original infected site.

In Europe, infected trees are removed within a week. If a tree cannot be removed immediately, it is cut off and the stump is treated with herbicide, since the virus can be spread from root suckers. In France, where PPV is well established, this method can reduce the disease from 10% to 1% in an orchard over a three-year period. Trees are inspected three to four times a year and are pulled on a regular basis. The recommendation is made that growers wait three years before replanting the orchard to stone fruit, but this recommendation is not often followed by growers because of high land costs.

Control: Protection From Spread by Aphids

At present, fruit trees cannot be completely protected from aphid inoculation with PPV. Insecticide applications can aid in reducing total aphid populations on fruit trees; however, it may take only one or a few aphids to inoculate a tree, and total or near-total aphid control is impossible to achieve.

In addition, the most efficient PPV aphid vector species may not even feed on or colonize stone fruits. Controlling this type of transmission is difficult because the aphids are so mobile. They need to probe for only a few seconds to acquire or transmit the virus, leaving little time to effectively apply a contact insecticide.

Also, controlling all potential aphid vectors requires scouting for different aphid species over the entire growing season. Some PPV vector species colonize peach only in early spring and then move to non-woody perennials during the summer; some aphids colonize peach during the growing season; and other species feed on peach only in the fall and lay eggs for overwinter survival on the trees.

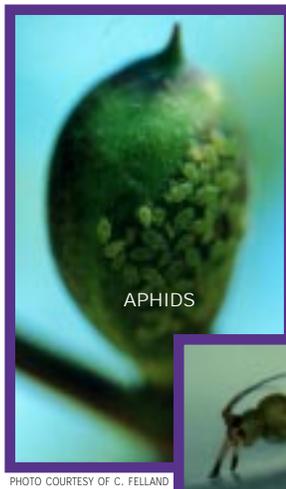


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Resistance: Plant Breeding and Genetic Engineering

If eradication of PPV from an area is not possible and trees cannot be adequately protected from virus inoculation by aphids, then plant resistance to the virus is the only remaining viable control strategy. Few naturally occurring resistance genes are available for plant breeders to use in developing highly resistant fruit varieties.

Hybrid plum cultivars have been identified that respond to PPV by a hypersensitive response. This means that once virus infection occurs, the plant tissue surrounding the infection site quickly dies. PPV, like all other viruses, can survive and multiply only in living host cells. Therefore, the hypersensitive response prevents spread of the virus to other parts of the tree and eliminates the virus from the host. Unfortunately, the hypersensitive response in these plum hybrids is regulated by several different genes in the tree, making it difficult to incorporate the hypersensitive trait to other cultivars by standard plant breeding methods.

At this time, the most progress in developing resistance to PPV has involved genetic engineering of resistant stone fruit species. Because few, if any, stone fruit genes resistant to PPV occur naturally, plant scientists have used novel genetic engineering techniques to insert specific PPV genes into stone fruit plants. For reasons that are not very well understood, incorporation of the PPV genes into plum causes the plant to become highly resistant or almost immune to PPV. Similar work also has been reported for apricot in France. This

type of resistance is inheritable and transmitted through seed and can be incorporated into other cultivars by standard plant breeding methods. Although this method is still only in the experimental stages, it is hoped that this type of resistance can be used to develop commercially viable cultivars of stone fruit crops.

FOR FURTHER INFORMATION

More information, including photos of PPV symptoms, can be found at the following WWW sites:

<http://sharka.cas.psu.edu>

http://www.state.pa.us/PA_Exec/Agriculture/plum_pox

REFERENCE

Brunt, A. A., Crabtree, K., Dallwitz, M. J., Gibbs, A. J., Watson, L. and Zurcher, E. J. (eds.) 1999. "Plum Pox Potyvirus." In: *Plant Viruses Online: Descriptions and Lists from the VIDE Database*. Version: 16th January, 1997. <http://biology.anu.edu.au/Groups/MES/vide/>

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SHARKA *Plum Pox Virus* UPDATE

CURRENT STATUS OF PLUM POX VIRUS

The following contains a summary of the current status of plum pox virus in Pennsylvania. Keep up with the latest information on plum pox virus on the Web at <http://sharka.cas.psu.edu>.

Initial Identification of Plum Pox Virus in Pennsylvania

A grower in Adams County first recognized the unusual symptoms of plum pox virus (PPV) on Encore peach. After a series of inquiries, a representative from the Pennsylvania Department of Agriculture (PDA) visited the site on September 23, 1999, and collected samples for laboratory analysis. By September 28, 1999, preliminary laboratory results indicated that plum pox virus was potentially the cause of the disease, so samples were sent to the U.S. Department of Agriculture for further testing. On October 12, 1999, USDA positively identified plum pox virus as the cause of the problem and identified it as Strain-D. Strain-D was found in both peach and plum samples.

Survey to Identify Infected Orchards

A survey of all stone fruits within a one-mile radius of the initial Encore peach orchard was begun on October 12, 1999,

to determine the extent of the disease distribution. Personnel from PDA and USDA were involved in the survey. Because testing for PPV requires fresh leaves, the time available to test for PPV-infected orchards in fall 1999 was very limited. The collectors walked diagonally across each orchard, collecting leaves from the mid-section of shoots. At the PDA laboratory, eight leaves from each sample were examined visually for symptoms then tested for the virus using laboratory techniques. The laboratory test being used can detect PPV even if there is only one infected leaf in a sample of 10 leaves. On October 20, 1999, the survey was expanded to include what would become the entire two-township quarantine area, a two-mile radius from the initial positive orchard block. Additional surveys were conducted in and around nurseries in Adams County, in orchards adjacent to the nurseries, and at some other Encore peach orchards. Weeds and wild stone fruit species, which are suspected of harboring the virus, also were tested. A windstorm on November 4, 1999, blew the leaves off the trees, terminating the survey.

Results of the Initial Survey

In Latimore and Huntington Townships in Adams County, 104 orchard blocks were sampled and tested. Fifty-seven orchard blocks in other parts of Adams County and 33 orchards in other counties were tested. Of the 218 orchard blocks sampled, 200 tested negative for plum pox virus. The 18 infected orchard blocks were all located in the area of Latimore and Huntington Townships. Of these 18 orchard blocks, only 2 showed visual symptoms. In all cases, weeds and wild stone fruit plants sampled were negative for the virus.

PDA placed quarantine on the two Adams County townships on November 6,

1999, which prohibited the movement of budwood or trees from the area. There is no restriction on the sale of fruit from the area since there is no evidence that the virus is spread from the fruit. There are approximately 1,000 acres of stone fruit in the infected area of the two Adams County townships.

Year 2000 Survey

In 2000, PDA will sample and test all peach orchards in Pennsylvania for PPV at least once. All the orchards in Adams County and surrounding counties will be sampled twice. In areas with infected orchards, door-to-door surveys also will be conducted to identify backyard stone fruit trees that may require testing.

Eradicating Infected Stone Fruit Orchards in 2000

All 18 stone fruit orchard blocks that tested positive for PPV last fall will be removed. If additional PPV-infected orchards are identified, they will be removed if more than 5 percent of the trees are infected with the virus. If fewer than 5 percent of the trees are infected, a USDA risk assessment team will evaluate the situation and make a recommendation about tree removal.

Commercial Orchard and Fruit Tree Nursery Indemnity Program

The Pennsylvania Drought, Orchard, and Nursery Indemnity and Flood Relief Act took effect on December 13, 1999. The act establishes the Commercial Orchard and Fruit Tree Nursery Indemnity Program, describes the circumstances under which grants are to be awarded, and appropriates \$2,000,000 to fund these grants. The program is intended to provide some financial relief to owners of commercial

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orchards and commercial tree fruit nurseries who incur costs related to controlling PPV.

People who wish to apply for a grant under the program may download an application form from the PDA Web site, <http://www.pda.state.pa.us>. Grant application forms also can be requested by calling (717) 772-5203 or by writing to the Pennsylvania Department of Agriculture, Bureau of Plant Industry, 2301 North Cameron Street, Harrisburg, PA 17110-9408.

Nurseries in Adams County

No nurseries located in Adams County are in the quarantine area. All nurseries and stone fruit orchards next to the nurseries tested negative for PPV when tested by PDA in 1999. Stone fruit trees budded with wood from the infected area are quarantined and will not be sold by the nurseries. Records indicate that nurseries located in Adams County have sold no stone fruit trees using bud wood from the quarantine area in the last five years.

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