Recovery Plan
for
Plum Pox Virus (Sharka) of Stone Fruits

July 17, 2014

Contents page

This recovery plan is one of several disease-specific documents produced as part of the National Plant Disease Recovery System (NPDRS) called for in Homeland Security Presidential Directive Number 9 (HSPD-9). The purpose of the NPDRS is to insure that the tools, infrastructure, communication networks, and capacity required to mitigate the impact of high consequence plant disease outbreaks are such that a reasonable level of crop production is maintained.

Each disease-specific plan is intended to provide a brief primer on the disease, assess the status of critical recovery components, and identify disease management research, extension and education needs. These documents are not intended to be stand-alone documents that address all of the many and varied aspects of plant disease outbreak and all of the decisions that must be made and actions taken to achieve effective response and recovery. They are, however, documents that will help USDA guide further efforts directed toward plant disease recovery.

Executive Summary

Plum pox virus (PPV) causes the most devastating viral disease of stone fruits. The disease is commonly referred to as Sharka in Europe. It was first reported in Bulgaria in the mid 1910's, and described as a viral disease in 1932. Sharka is one of the most serious diseases of stone fruits in terms of economic and agronomic impacts. PPV reduces fruit yield and marketability. Infected fruit trees are rendered useless for fruit production and the productive lifespan of orchards is shortened. Different strains of PPV may infect a variety of stone fruits from the *Prunus* family including peaches, apricots, plums, nectarines, almonds and sweet and tart cherries. Wild and ornamental species of *Prunus* may also become infected by some strains of the virus.

Symptoms of PPV vary with the timing of infection, virus strain, *Prunus* species, cultivar, and environment. Visual symptoms may appear on leaves, fruit, flowers, and the stone (seed). Leaves show yellow or light green patterns, bands, or blotches. The fruit may have similar symptoms. The symptoms occur sporadically due to an uneven virus distribution within an infected tree. Newly infected trees are rarely symptomatic and visual symptoms are often not apparent until three or more years after infection.

PPV isolates can be classified into nine strains: D (Dideron), M (Marcus), C (Cherry), EA (El Amar), W (Winona), Rec (Recombinant), T (Turkish), An (Albania), and CR (Cherry-Russian) (Garcia et al., 2014). Most PPV isolates belong to the D and M strains and recombinants between the D and M strains have been described as PPV-Rec. A second type of recombinant isolate was reported in Turkey (strain T). Recently, a new strain (CR) that infects sour cherry was identified in Russia (Chirkov et al., 2013; Glasa et al., 2013). An additional putative PPV strain (PPV-An) could be represented by a recently identified isolate from eastern Albania (Palmisano et al., 2012).

In North America, PPV was first found in Pennsylvania in 1999, in Canada in 2000, and in Michigan and New York in 2006. Among the nine different strains of PPV that have been isolated so far, only strain D occurs in fruit trees in the United States. PPV strain D naturally infects plums, peaches, nectarines and apricots. It can also infect wild and ornamental *Prunus*, such as Korean cherry, black cherry, and American wild plum. The disease threatens the productivity and economic profitability of the nation's stone fruit industry. Several years (2000-2013) of a national survey of stone fruit orchards have found the disease limited to a small region in south central Pennsylvania, western New York, and an experimental orchard in Michigan, although no positive trees have been found in 2012 and 2013, and so far in 2014.

In Pennsylvania, intensive surveys for PPV and aggressive orchard eradication efforts from 1999 through mid 2006, followed by an intensive post-eradication monitoring program from 2007 to 2009 resulted in the removal of 1,675 acres of stone fruit trees. Some individual PA growers in the PPV-infected area lost all of their peach and nectarine production, ending decades of stone fruit production on their family farms. In 2010, PA officially declared eradication and the PPV-free status was subsequently confirmed through a less intensive post-eradication monitoring in 2010-2012.

In Michigan, PPV was detected in a single plum tree located at a Michigan State University experimental orchard facility in 2006. The infected tree was destroyed along with all susceptible hosts within 500 meters of the positive tree. Sustained investigations showed no additional trees infected with PPV in Michigan. The virus is considered eradicated in Michigan. Based on this isolated incidence and its related eradication success, the remainder of the Recovery Plan will primarily focus on the situations in Pennsylvania and New York.

In New York, PPV was confirmed in a plum orchard and in a peach orchard in Niagara County in 2006. The plum site was a short distance east of the Niagara River and the peach site was roughly 11 miles to the east of the first site. Survey in 2007 resulted in the detection of an additional 20 positive trees in five orchards in Niagara County and in Orleans County. The 2008 surveys generated 10 more positive trees in orchards in close proximity to previous positives, except for two new positive sites in two orchards in Wayne County. The 2009 surveys generated 15 more positive trees in Niagara (one site), Orleans (one site) and Wayne Counties (four sites). In 2010, two positive trees were found in Niagara in two orchards and a single positive tree was identified in Niagara County in 2011. No positive trees were found in 2012 and 2013. So far, no positive trees have been identified in New York in 2014.

Eradication efforts in New York resulted in the removal of 26.7 acres of orchards in 2007 followed by 16.24 acres in 2008, 29.36 acres in 2009, 18.35 acres in 2010, and 29.02 acres in 2012. The New York State Department of Agriculture and Markets (NYSDAM) and USDA-APHIS-PPQ crews continue surveying commercial and abandoned orchards, as well as homeowner properties in eight of the 20 stone fruit-producing counties in New York. After three years of negative survey, some of the first NY quarantined areas were released for replanting in 2009 and in subsequent years in Niagara, Wayne and Orleans Counties. As a result of extensive survey findings, no new positives were found in NY since 2010, except one find in 2011 in Niagara County.

Since 1999, orchard surveys and eradication efforts have been a model of cooperation between growers, extension educators, land-grant universities, State departments of agriculture, and government and university researchers, as well as state, and federal regulatory agencies. Funding programs approved by state and federal governments have facilitated grower and extension education about PPV, yearly orchard surveys, quarantine and eradication programs, and grower's compensation for removed acreage. As a result, the PPV level in PA and NY orchards decreased rapidly over time. At the farm level, early successes have resulted in several quarantine zones being removed beginning in 2004 in PA and in 2009 in NY after three consecutive years of negative survey and testing results for the virus. Grower cooperation has been and remains high throughout the PPV eradication efforts from 1999 through 2014.

There is no evidence that PPV infected plant material has entered the distribution system in the United States since 1999, although infected hand-carried budwood that was illegally introduced was intercepted a few years ago (Mavrodieva et al. 2013). PPV has been eradicated in Pennsylvania and in Michigan. Eradication efforts are still ongoing in NY with no new positive tree found in 2012 and 2013, and so far in 2014.

Some concerns that may affect the final success of the program in New York remain among growers, extension educators, regulators and the scientific community:

- The proximity of the New York stone fruit industry to Ontario, Canada - where PPV has not been fully eradicated, infected trees are deliberately maintained in orchards, and recent monitoring efforts target outskirts of quarantine zones - has the potential to jeopardize the short and long-term success of the eradication program.
- In 2011, Canada transitioned from an eradication program to a monitoring program for the management of PPV. There is little doubt that this decision has profound implications for the long-term success of the eradication program in NY.
- Border surveys along the Niagara River were neglected since the start of the eradication program in NY. Border surveys started only in 2012 under the auspices of NYSDAM. Those surveys should be intensified in the future.
- Federal resources allocated to the eradication program in NY have been substantially reduced in recent years, jeopardizing opportunities to achieve full eradication in a timely manner.
- Reduced federal resources are made available late in the season, hindering optimized coordination efforts among the different partners. To achieve full eradication, a strategically coordinated approach is crucial for an effective program; a sub-optimal strategic planning will reduce the effectiveness of ongoing efforts to achieve full eradication in a timely manner in New York.
- NAPPO regional standards for phytosanitary measures following detection of PPV (RSPM No. 18) are being revised and there are serious risks for lower standards to be considered for accommodating the Canadian transition from an eradication program to a monitoring program. Any complaisance with reduced standards would have detrimental consequences on U.S. eradication efforts.
- There are serious concerns about the potential for the NY eradication program to drag because of lack for appropriate resources and suboptimal coordination of efforts to achieve full eradication in a timely manner, as well as a lack of federal diligence with regard to the Canadian decision to adopt a monitoring program.
- Combining commercial orchard and residential surveys would reduce travel distances and consolidate resources; similarly, processing and testing samples in NY would reduce overall program costs.
- Increased communication transparency on trace back samples would have the merit to facilitate the identification of potential sources of infected budwood, providing opportunities to prevent future outbreaks.

The ultimate goal of the PPV eradication program is to successfully eliminate PPV from the New York and United States stone fruit industry. To achieve this goal, surveys must be continued diligently and aggressively in New York for several more years in order to ensure a full eradication of PPV.

Contributors

Cornell University

- M. Fuchs*, Associate Professor, Department of Plant Pathology and Plant-Microbe Biology, marc.fuchs@cornell.edu (*Chair and corresponding author)

New York State Department of Agriculture and Markets

- C. Logue, Director, Division of Plant Industry, Christopher.Logue@agriculture.ny.gov
- M. Kelly, Assistant Director, Division of Plant Industry, Margaret.Kelly@agriculture.ny.gov
- P. Sierzenga, Horticultural Inspector, Division of Plant Industry, Patricia.Sierzenga@agriculture.ny.gov

Pennsylvania Department of Agriculture

- Ruth Welliver, Plant Pathology Program Manager, rwelliver@pa.gov

List of experts

- Mariano Cambra, Centro de Proteccíon Vegetal y Biotechnolgía, Instituto Valenciano de Investigaciones Agrarias, Moncada, Valencia, Spain, mcambra@ivia.es
- Delano James, Center for Plant Health, Sidney, BC, Canada, Delano.James@inspection.gc.ca
- Rick Mumford, Food and Environment Research Agency, York, UK, rick.mumford@fera.gsi.gov.uk
- Tim Gottwald, USDA-ARS, US Horticultural Research Laboratory, Fort Pierce, FL, Tom.Gottwald@ars.usda.gov
- Ralph Scorza, USDA-ARS, Appalachian Fruit Research Laboratory, Kearneysville, WV, Ralph.Scorza@ars.usda.gov

Recovery Plan
for
Plum Pox Virus (Sharka) of Stone Fruits

I. Introduction

Plum pox virus (PPV) is a serious disease of stone fruits worldwide. The disease was first observed in Bulgaria in the mid 1910's. It was given the name Sharka, which is Slavic for plum pox. PPV is an important disease across Europe where it causes significant economic loss due to a reduction in fruit quality and yield, and shortened productive lifespan of trees in the orchard. From Bulgaria, the virus rapidly spread to neighboring countries, eastern Europe, western and northern Europe, Africa, South and North America and Asia within less than a century. PPV was found in South America in 1992 and in North America in 1999. Annual costs of Sharka management worldwide are conservatively estimated at $441 million (Cambra et al. 2006).

In the United States, PPV was found in Pennsylvania beginning in 1999, and in New York and Michigan in 2006. PPV was identified in Ontario, Canada in 2000. The strain of the virus identified in PA and NY, known as PPV-D, infects stone fruits (*Prunus*) including plum, peach, nectarine and apricot, as well as many related ornamental *Prunus* species. Sweet and sour cherry are not known to be naturally infected by PPV strain D. How PPV was brought into PA and NY is uncertain, although infected plant material used for propagation is considered the most likely mode of introduction. Once introduced into an area, the virus can spread through aphid feeding.

II. Symptoms

PPV causes several different types of symptoms on different parts of the tree and at different times of the growing season. PPV symptoms are generally similar on peaches, nectarines, plums and apricots. Symptoms do not normally begin to appear on the tree until about three years after the infection takes place. While visual symptoms can be very useful for diagnosis, the absence of symptoms is not a guarantee of the disease status of fruit trees, as many infected trees or cultivars may remain symptomless. The only sure method of detecting PPV is through laboratory screening tests. The US eradication program has therefore focused on detection through leaf collection and analysis in the laboratory rather than relying on PPV symptoms expressed in the orchard.

Blossoms. The first symptom that may be observed is blossom streaking on peach (Figure 1). Characteristic color streaking of peach flower blossoms in association with PPV infection has been reported in some European regions but not others. This blossom streaking symptom was never observed in New York and only once in Pennsylvania although disease level was so low in PA orchards and bloom time is so short that it makes searching for this symptom impractical. It would be difficult for an orchard observer to detect blossom streaking since peach blossoms are often very showy, making detection of

small differences in coloring difficult to detect, particularly since streaking is reported to vary even from petal to petal or tree to tree.

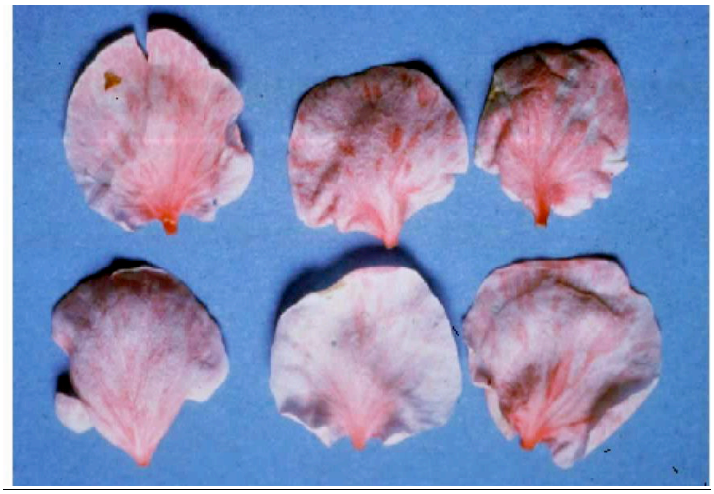

Figure 1. Peach blossom streaking caused by *Plum pox virus*. Courtesy of J. B. Quiot, Southern France.

Leaves. Several types of symptoms may occur on leaves. PPV may cause leaves to have faint light green to yellow ring spots or halos about the size of a pencil eraser or smaller scattered across the leaf. Leaves may also exhibit a yellow netting pattern which is often accompanied by veins that are lighter green than normal to yellow in color (Figure 2). Leaves may be distorted or twisted as a result of infection. Symptoms may also include vein yellowing or light green to yellow rings. Plums often exhibit acute symptoms, including chlorotic and necrotic ring patterns or blotches. Peach leaves may show leaf crinkling, puckering or curling. Apricot leaves usually show lighter symptoms than plum or peach.

Figure 2. Leaves with yellow netting and distortion caused by *Plum pox virus*. Courtesy of J.W. Travis, Adams Co., PA.

Symptoms appear on the first leaves to develop on new infected shoots in the spring. These leaves occur at the base of new shoots and symptoms will often be visible until temperatures reach 85 to 95 degrees F in late spring and summer at which time the virus symptoms fade and are no longer visible. When looking for PPV leaf symptoms, scouts observe the leaves on the lower (basal) 1/3 of the shoot since leaves that are produced after early spring do not show symptoms even if the shoot is infected while more basal leaves can exhibit PPV symptoms. Not all infected branches and shoots on an infected PPV tree produce leaves with PPV symptoms. Symptoms may be more pronounced and more widespread through the tree in younger than older trees, and in plum more than peach.

Fruit. While the blossom and leaf symptoms can be easily missed, it was the bold yellow ring spots on the red skins of peach fruit of the cultivar Encore that first made the PA fruit grower who found PPV aware that there was an unusual and serious problem with his fruit (Figure 3). Some stone fruit cultivars show no symptoms after infection while others like Encore peach display pronounced PPV symptoms about three years after the tree is infected. At first only a few fruit show the symptoms but eventually nearly all the fruits on the tree are spotted and the symptoms become easier to see as the fruit ripens.

Figure 3. Yellow halos and ring spots on peach fruit caused by *Plum pox virus*. Courtesy R. Welliver, Adams Co., PA.

The yellow halos on the fruit are only skin-deep and are removed with the skin, however, the fruit is worthless for fresh fruit sales for cosmetic reasons due to the blemish. The symptoms become easier to see as the fruit ripens. On some fruit cultivars, the fruits are abnormally formed and distorted by PPV infection. Some apricots also have distinct PPV

yellow halos on the seeds (Figure 4). Premature fruit drop that occurs as the fruits are beginning to ripen is another devastating symptom of PPV infection in plums. The ground under PPV infected plum trees may be covered with fruit lost just before harvest.

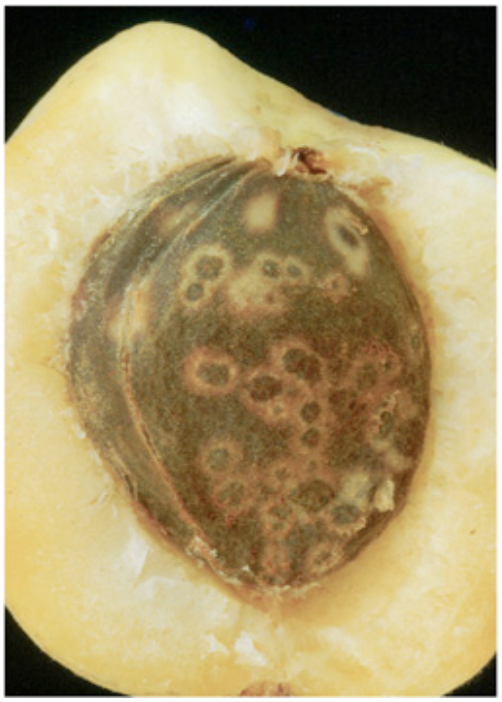

Figure 4. Yellow halos on the surface of the seed of an apricot fruit infected with *Plum pox virus*. Courtesy M. Cambra, IVIA, Moncada, Spain.

III. History and Spread of PPV in the United States

PPV is spread naturally by aphid vectors and through propagation and grafting of infected budwood via human activities. There is general agreement that the original source of PPV to the United States occurred through infected plant material. However, the actual incident and location of the original infection has not been conclusively identified either in Pennsylvania or in New York.

In Pennsylvania, based on initial finds and expected follow-up spread by aphids, the original orchard infection probably occurred in northern Adams County in or before 1991. PPV was first positively identified in September of 1999 in Pennsylvania by the PA Department of Agriculture and verified by the USDA. However, as early as 1996-97 an Adams county fruit grower had recognized unusual spotting symptoms developing on his Encore peaches and had tried unsuccessfully to learn the cause. Because PPV had never occurred in the United States, very few industry personnel or academic researchers associated with the stone fruit industry were familiar with PPV symptoms and the disease remained unreported. In 1999, after seeing the symptoms for several seasons and with no success in learning the cause, the grower sent infected fruits to a New Jersey fruit extension specialist who had seen PPV in Europe and suspected PPV. Extension personnel from PA simultaneously contacted the PA Department of Agriculture, who forwarded fruit to the USDA quarantine facility for definitive identification.

Once introduced in an area the primary risk of spread of the virus is through distribution of infected nursery plant material and from tree to tree or orchard to orchard by aphids. Initially, nursery stock was believed to be at risk of having spread PPV infected plant material since budwood had been cut by two PA commercial nurseries from orchards in the area where PPV was identified. However, after extensive nursery stock surveys and tracking new orchards established from nursery material over the previous several years, it became evident that the local nurseries did not spread PPV through the sale of infected nursery material. A similar situation was experienced in NY. The absence of nursery spread was very fortunate and one of the most important factors that will contribute to the ultimate success of PPV eradication in the United States. Although every state with a stone fruit industry was surveyed intensively for three years, no other infected PPV orchards have been found outside of Pennsylvania until the 2006 findings in New York and Michigan. In 2000, two of the commercial nurseries in the PA quarantine area moved their stone fruit plant propagation to a near-by state where PPV was not found to prevent any additional risk of spread from the nursery trees.

Following the initial introduction of infected planting material to PA, aphids likely spread the virus from the original infected orchard to adjacent orchards. Aphids are poor flyers, so the spread occurred in the direction of prevailing wind currents. Several species of aphids common to Adams county PA that are capable of spreading the virus have been identified. However, recent research indicates that aphids are not efficient carriers or transmitters of the virus. Fortunately for local and US fruit industry, aphid spread of the virus was at a slow rate and did not progress far from the original PPV infected orchard. This has permitted the eradication efforts to concentrate on a limited geographical area in PA greatly increasing the potential for success. In contrast, PPV has become endemic in extended fruit producing regions in France and Spain as well as in many other countries, preventing eradication of infected trees resulting in the continued spread of the virus disease by aphids. This has resulted in devastating losses in production and profitability to the fruit industry of these countries. In some regions, alternative crops were required to replace stone fruit production.

Following the initial detection of PPV in Adams County, PA, there was concern that aphids might spread PPV into wild plant hosts including several common weed species. If PPV were to become established in indigenous native plants and weeds, eradication would become very difficult. Fortunately, extensive surveys conducted annually over a 6-year period of potential wild plant hosts have identified none that were infected with PPV. It was also recognized early that if infected fruit had been culled from local PA fruit packing lines and dumped in outside cull piles that aphids may be capable of spreading the virus from the infected fruit to healthy near-by stone fruit orchards. Some circumstantial evidence suggested that this could have happened on a small scale. For this reason, steps have been taken to prevent the potential spread from fruit culls.

In New York, PPV was confirmed at two sites in Niagara County in 2006. The first site was in a plum orchard a short distance east of the Niagara River. The second site was located in a peach orchard, roughly 11 miles to the east of the first site. As a result, New

York implemented an eradication program in conjunction with USDA-APHIS-PPQ and adopted a buffer zone of at least 50m. Survey in 2007 generated 87,876 samples that resulted in the detection of an additional 20 positive trees in five orchards. Four of the sites were located in Niagara County within five miles of a 2006 positive site. The fifth orchard was located 22 miles to the east of the closest Niagara County positive in Orleans County. A total of 26.7 acres of orchards were destroyed in 2007 because of the positive detections in 2006 and 2007. The 2008 surveys generated 106,347 samples of which 10 were positive. All of the positive sites were in orchards in close proximity to previous positives except for new positive sites confirmed in two orchards in Wayne County. These two sites were 60 miles east of any other known positive sites. Eradication efforts in 2008 resulted in the removal of an additional 16.24 acres of stone fruits. The 2009 orchard survey resulted in the detection of 15 samples being confirmed positive in six different locations. The six positive sites were located in Niagara (one site), Orleans (one site), and Wayne Counties (four sites), as a result of 167,602 samples being collected and tested from commercial and abandoned orchards, and homeowner properties in eight counties. Eradication efforts in 2009 resulted in the removal of an additional 29.36 acres of *Prunus*. After three years of negative survey one of NY's first quarantined areas in Niagara County was released for replanting in 2013. This area, quarantined in 2006, had tested negative for the past three years, meeting the requirements for release. No new positives were found among the 250,746 samples collected in 2010 but a single positive tree out of 161,492 samples collected in 2011 was found in Niagara County. In 2012, 155,927 leaf samples were collected in 16 counties and no positive was found. A total of 18.35 and 29.02 acres of peach was removed in 2010 and 2012, respectively, as a consequence of the 2010 and 2011 finds. In 2013, 125,050 leaf samples were collected and no positive was found. Although the 2014 surveys have yet to be completed, no positive has been found so far.

Table 1: Surveys of *Plum pox virus* in New York

Year	Samples	Positive Sites	Positive Trees	Positive County	Removal (acres)
2000	17,768	0	0	na	na
2001	12,879	0	0	na	na
2002	15,960	0	0	na	na
2003	13,957	0	0	na	na
2004	14,494	0	0	na	na
2005	14,019	0	0	na	na
2006	87,876	2	3	Niagara	na
2007	91,425	5	20	Niagara, Orleans	26.70
2008	106,347	4	10	Niagara, Orleans, Wayne	16.24
2009	167,602	6	15	Niagara, Orleans, Wayne	29.36
2010	250,746	2	2	Niagara	18.35
2011	161,492	1	1	Niagara	na
2012	155,927	0	0	na	29.02
2013	125,050	0	0	na	na
2014	underway	na	na	na	na
Total	1,070,338	18	50	Niagara, Orleans, Wayne	119.67

Starting in 2012, a border survey was conducted for the first time by the NY State Department of Agriculture and Markets (NYSDAM). The location of the border survey was the western boundary of Niagara County that is adjacent to the Niagara River. The Niagara River is between Niagara County, NY and Ontario, Canada. Just across the Niagara River within Ontario is a stone fruit-growing region for Canada. PPV is known to occur in this region and there is no longer an effort to eradicate the disease from Canada. The presence of PPV in such close proximity to the major NY stone fruit-growing region puts this industry (and the United States' industry) at risk, especially the Niagara County growers. In 2012, over 1,062 acres along the border were extensively surveyed for the presence of susceptible *Prunus* species. A total of 245 samples were collected, processed and tested in 2012 and several additional hundreds of samples were GIS-mapped in preparation for subsequent surveys. Border surveys have not indicated yet a positive tree along the Niagara River.

Based on the distribution pattern of infected trees (5 to 60 miles apart), the occurrence of PPV primarily in processing peaches (with the exception of one of the initial finds in Castleton plums in 2006), and the fact that some growers recognize the introduction and use of budwood from affected orchards in Ontario, Canada, there is limited, if any, evidence to support an active aphid-mediated dispersal of PPV in New York. Budwood seems to be the primary source of inoculum in New York. Nonetheless, aphids could be involved in some level of PPV dispersal in the case of newly infected trees in close spatial proximity to previous finds. The fact that aphids are not efficient transmitters of PPV contributes to a successful eradication program in New York. However, the spatial proximity to Ontario, Canada raises serious concerns on the future success of the NY eradication program.

USDA and NYSDAM personnel conducted a survey of residential properties within one mile and up to five miles from previous positive finds in commercial orchards. No residential samples were positive from 2006-2013. In 2011, the first regulated area in Wayne County was released. In 2012 and 2013, there were no positive finds in the orchard, residential or border surveys. This is the first time since the initial detection in 2006 that there have been no positives. This enabled the deregulation of three regulated areas in Wayne and Orleans Counties at the end of 2012 and of one regulated area in Niagara County at the end of 2013. This is a significant milestone in that commercial growers in these areas formerly regulated can once again plant *Prunus* trees. The planting of replacement trees is critical to maintain peach and other stone fruit orchards, and sustain the profitability of the local industry. However, the Nursery Quarantine remained in effect in 2013 and 2014, prohibiting propagation and growing trees.

The 2013 NY surveys were planned to gain efficiencies, address border concerns and get closer to eradication with the residential, commercial and border surveys being conducted only by NYSDAM personnel. By combining these surveys, travel distances were reduced, resources consolidated and areas of duplication reduced. Work schedules were managed to allow contacting residential property owners at times they are more likely to be home – evenings and weekends. This reduced the need for return visits to obtain permission for property access. The combination of three surveys being conducted by

one team allowed flexibility to respond to resampling needs and fluctuating grower spray schedules. Unfortunately, these optimally managed surveys were not conducted any longer in 2014. This will certainly reduce opportunities for an optimal management of limited resources allocated to the PPV eradication program in NY.

IV. Economic Impact and Compensation

Stone fruit production is an important part of the United States agricultural economy. The yearly value of production of peaches (112,880 acres), nectarines (26,400 acres), plums (80,000 acres) and apricots (12,150 acres) nationally was approximately $1.5 billion in 2012 (USDA-NASS).

In Pennsylvania, the peach industry ranked fifth nationally in production with about 6,500 acres in 1999 (PA Agric. Statistics Service). In 1999, about 44% of the PA stone fruit acreage was located in Adams County where PPV was found. The annual value of PA stone fruits was approximately $22.3 M in 1999. In 2012, PA ranked fourth nationally in peach acreage (4,400 acres) and fifth in peach production (20,800 tons) for a $22 M value (USDA-NASS).

Soon after PPV was discovered in Adams County, PA and state and federal destruction orders were issued, growers began working with local and state Penn State Cooperative Extension personnel to develop an indemnification program compensating growers for the lost production of trees that were destroyed due to PPV. The first orchards were removed prior to any guarantee of compensation programs being approved by state or federal governments. This evidence of the high degree of grower cooperation in the eradication of PPV from the United States has been demonstrated throughout the PPV eradication process.

The Pennsylvania legislature led by local state legislators responded very quickly by enacting the Drought, Orchard, and Nursery Indemnity and Flood Relief Act on December 13, 1999. The act provided $2M ($3.1M –May 2000) for indemnification and removal and destruction of trees. The state funding was renewed each year since its initiation. The indemnification program is based on the value of the tree that takes into account the remainder of the average life of a productive commercial orchard in Pennsylvania. A grower/extension formula for compensation was slightly modified and adopted by the USDA in November 2000.

The destruction orders given to growers provide them 10 days to begin to remove the trees. There has been much appreciated flexibility by Pennsylvania Department of Agriculture and USDA in allowing growers to harvest their crop before removing the trees if harvest occurs within a few weeks of the destruction order. Some growers harvested the crop and removed the trees immediately after receiving the destruction orders while others removed the trees with a full crop on the trees. Growers are compensated for tree removal, pest control prior to removal, site preparation, cover crop establishment, and estimated orchard productivity over the remainder of the life of the orchard. The federal government passed legislation to pay $15M in PPV indemnity

payments as part of the Agricultural Risk Protection Act in June 2000. A payment program was published in the Federal Register in September 2000. The USDA has provided 85% of the indemnification funds while PDA is providing 15% of the funding. In 2006, over $26M have been paid to growers for indemnification from state and federal sources. Some of the first growers to remove trees in the winter of 2000 were still not permitted to replant in the spring of 2006. However, the quarantine has been removed in some areas and growers have been permitted to replant stone fruits.

In 2000, Penn State Cooperative Extension performed an economic impact study that determined that the economic loss to the community, not including growers for every 1,000 acres of trees removed would be $1.6M per year. This impact is in jobs, taxes paid to school districts, townships and the county. It also accounts for the effect on equipment dealers, fuel suppliers and suppliers to the growers. Nearly 1,500 acres of stone fruits have been destroyed in PA due to PPV through the fall of 2005, six years since PPV was first identified. Therefore, the approximate cost to the community, excluding the fruit growers has been about $14.4 M over a 6-year period.

In New York, 1,700 acres of peaches were grown in 2006 when the first PPV-infected trees were identified. This acreage dropped to 1,600 acres by 2008. Since then it has remained relatively constant in spite of the removal of approximately 5% of the total acreage due to the presence of PPV in the State (USDA-NASS). The value of the peach industry was $4.11 million in 2012 with a production of 2,600 tons, ranking New York 11th in terms of peach acreage but 19th in the US in terms of peach production - due to severe frost damage that year.

The compensation provisions for orchards and nurseries affected by PPV were updated in 2012. The amendment for the payment of compensation to eligible owners of commercial stone fruit orchards and fruit tree nurseries whose trees are required to be destroyed in order to prevent the spread of PPV was welcome in New York. The former compensation rates were promulgated in 2000 and revised in 2004 during the initial PPV outbreak in Pennsylvania. Since the 2004 final rules, no adjustments to the compensation provisions of the regulations were made. However, earnings by stone fruit growers and nurseries have substantially changed in recent years due to inflation and changes in management practices. The application of the original rates put NY growers at a disadvantage because orchards are traditionally planted at higher densities. As a consequence, more trees are impacted by the mandatory quarantine and removal when PPV is detected. Also, the value of the NY stone fruit industry has nearly doubled since 2000. Therefore, NY growers were not fully compensated for the loss incurred from the tree removals. The new compensation rates were proposed by NY stone fruit growers who worked diligently with Dr. Gerald White from the Dyson School of Applied Economics and Management at Cornell University and Alison De Marree, Cornell Cooperation Extension, Lake Ontario Fruit Program. The new rates more accurately reflect the loss a grower incurs when trees are removed in support of the PPV eradication program in New York.

Orchard and nursery growers are compensated for their loss through an 85-15 federal-state cost share program. An example of the new compensation rates is that an acre of three-year old trees was increased from $9,429/acre to $12,737/acre. It is anticipated that the long-overdue revisions of the compensation rates will help continue ensuring compliance with the PPV quarantine program, reducing the economic effect of the PPV quarantine program on affected commercial growers and nursery owners, ensuring the continued cooperation with the survey and eradication activities being conducted by USDA and NYSDAM, and providing an incentive to growers for maintaining a buffer zone around positive sites.

V. Surveys and Detection

In Pennsylvania, surveys began in the fall of 1999 soon after PPV was positively identified in an Encore peach orchard in Adams County, PA. After testing by the PA Department of Agriculture and the USDA-APHIS-PPQ laboratory in Beltsville, MD, the peaches were confirmed infected with the D strain of PPV. State and federal quarantines were placed on townships in PA where PPV was detected, permitting no replanting or removal of stone fruit seedling or vegetative plant material from the area. When PPV-infected trees were found, the removal of whole orchard blocks as well as residential and wild *Prunus* trees was required (Figure 5).

Figure 5. Removal of *Prunus* trees in an orchard infected with *Plum pox virus*. Courtesy of J.W. Travis, Adams Co., PA.

In 2001, the eradication zone was extended to include a 500-meter buffer around infected trees and orchards. In 2000 surveys were conducted in all the major stone fruit growing states (MI, NY, SC, NC, MD, GA and CA) with the most concentrated efforts occurring in PA. Fortunately for the US stone fruit industry, PPV was not widespread being detected only in a small fruit production region in southern PA a few miles north of Gettysburg. Commercial orchard samples are tracked by a number referring to the

county, grower, and orchard block using barcode tags in the orchards and on leaf sample bags for identification. A hierarchical survey protocol (one four-leaf sample from 25% of the orchard trees) was followed for areas more than five miles from quarantined areas. Within quarantine areas, recently rescinded quarantine areas and areas up to five miles from a previously positive site, every tree was sampled at either 4 or 8 leaves per tree. Tissue samples are collected from commercial orchard trees, residential properties, nursery and budwood source trees, sentinel trees and wild trees. The sampling goal by 2005 was to sample every tree in commercial orchards and residential properties in the quarantine zones and surrounding areas on a yearly basis and to sample *Prunus* orchards outside the quarantine area on a three-year rotation. Sampling generally begins in early May and concludes the end of August. A total of 213,005 leaf samples were collected from commercial orchards in 2005. Initially, all stone fruit orchards in the state of PA were surveyed by collecting samples from every fourth tree in orchards outside the quarantine area and from every tree sampled inside the quarantine zone. Over the next six years, the quarantine zone was extended to portions of three other counties adjoining Adams County. None of the additional trees found to be positive for PPV were more than 50 miles from the original PPV quarantine zone.

In 2001, the first PPV positive trees were found outside commercial orchards on a residential property. Extensive surveys of stone fruit trees in residential properties were also systematically carried-out in the PPV quarantine areas and within five miles of the quarantine. Leaf samples consist of eight leaves from each identified *Prunus* on the property. In 2005, 66,478 residential properties were visited with 50,609 trees sampled for PPV. From 2001 through 2005, several positive PPV homeowner trees were identified which in some cases expanded the quarantine area and resulted in additional commercial orchard removal.

After six years of sampling and testing, no PPV had been found in the United States outside of the quarantine zone in PA and fortunately PPV did not enter the United States nursery distribution system. The PA quarantine once included about 250 square miles but was reduced in size due to three consecutive years without a positive to about 200 square miles by 2005. From 1999 through 2006, 1,675 acres of commercial orchard and trees on approximately 190 residential properties had been destroyed. The last positive detected in Pennsylvania was in 2006, despite sampling and testing every year thereafter. Commercial fruit growers and the community have made a significant sacrifice to rid the United States of this disease.

Nursery production of *Prunus* has been suspended in (i) quarantine zones, (ii) within areas 11.5 km from a positive tree found in the previous three years, and (iii) quarantine areas for three years after the primary quarantine has been rescinded. In addition, propagators of susceptible *Prunus* within PA must have all bud wood sources tested for PPV. Due to these restrictions, *Prunus* nursery production is limited to areas outside Adams County and in some cases has been moved to nearby states. In 2005, four *Prunus* propagation nurseries, located in and outside PA, were tested with all nursery and budwood sources testing negative for PPV. No positive detections have been made in PA nurseries since.

PPV was detected in Canada in the Niagara Peninsula in 2000. There were concerns that the stone fruit growing areas in Michigan and New York near Ontario could also be infected with the virus. The region was intensively surveyed from 2000 through 2005 with no trees testing positive for PPV. In 2006, PPV was found in both Michigan and New York State. The virus was found in two locations in Niagara County, New York on July 10, and August 21, 2006. A plum tree was also found infected with PPV at the Southwest Michigan Research and Experiment Center on August 11, 2006. Extensive testing followed these two finds but no additional stone fruit trees were found infected with the virus in Michigan.

In New York, the eradication zone relied on at least a 50-meter buffer around infected trees. In 2007, 26.7 acres of plum and peach orchards were removed followed by 16.24 acres of peach in 2008, 29.36 acres of peach in 2009, 18.35 acres of peach in 2010 (Figure 6), and 29.02 acres of peach in 2012.

Figure 6. Destruction of a peach orchard infected with *Plum pox virus* in New York. Photo credit: M. Fuchs

Detection

In Pennsylvania and New York, orchards were sampled utilizing a hierarchical grid (Hughes et al., 2002). In PA during 2000 and 2001, one-fourth of all trees in an orchard were sampled in a specific pattern, with the quadrant being sampled randomly chosen each year. Trees were marked with a bar code, which identified the grower and tree number. Four leaves were collected from each of the four compass points on the tree. All 16 leaves were placed into a plastic bag receiving the same bar code identification as

the tree. This permitted accurate identification of each tree in the event that a positive result triggered additional sampling to affirm a positive PPV tree. Leaf samples were placed into plastic bags and placed in ice chests to be taken to a cold room storage facility the same day. Samples were systematically tested using first a serological technique known as double antibody (DAS) enzyme-linked immunosorbent assay (ELISA) followed by reverse transcription (RT) polymerase chain reaction (PCR) if a positive result occurred from ELISA following protocols provided by USDA. During 2002, the third year of sampling in PA, every tree in the quarantine areas was sampled while continuing the hierarchical sampling scheme for the remainder of the state outside the quarantine area. A sentinel tree system was established in the quarantine area in 2002. In 2003, the sample size per tree in the quarantine zone was increased to 8 leaves per tree and the first positive for PPV was found in a nursery late in the season.

A sentinel tree program was begun in 2002 as a warning system for PPV in quarantine zones. The sentinel trees are highly susceptible trees to PPV and were useful for detection since many of the *Prunus* trees in a quarantine zone have been removed. By 2005, 197 sites with over 500 sentinel trees were established in critical PPV areas. Each tree was sampled twice a year and all sentinel trees have tested negative to PPV. A sentinel tree program was not implemented in NY. In a related effort in PA, regrowth root sprouts from removed trees and seedlings at stone fruit dump sites have been sampled, tested, and found negative for PPV (Figure 7). This program was not implemented in NY.

Figure 7. Root sprouts after tree removal in an orchard infected with *Plum pox virus*. Courtesy of J.W. Travis, Adam Co., PA.

Growers have been instructed to control root sprouts after tree removal and eliminate

fruit cull piles to reduce the risk of these sites serving as a source for PPV. Weeds have been surveyed for six years in the vicinity of PPV infected orchards. Leaves of weeds and wild *Prunus* trees are sampled weekly during the growing season and tested for PPV. Over the six years, 65,461 samples have been tested and found negative for PPV. Since 2002, 23,498 herbaceous bait plants have been located in PPV quarantine areas and later tested with all found to be negative for PPV. This program was not implemented in NY.

VI. Monitoring and Identification of Aphid Populations in the Vicinity of PA *Prunus*

In Pennsylvania, monitoring of aphid populations has been conducted in commercial orchards, residential properties and in sentinel trees beginning in 2000 and continuing through 2006. The project objectives were to identify potential aphid vectors of PPV and determine seasonal variation. In summary, 29 different species of aphids were identified with the fewest number of aphid species occurring in commercial *Prunus* orchards as a result of effective pest management programs. Higher numbers of aphid species were collected on sentinel trees, which receive less intense pest management than commercial orchards. Because of higher aphid numbers, the sentinel trees may serve their intended purpose and be the first indicators of PPV resurgence or reintroduction into the area. The peak time for aphid species collection in commercial orchard occurred in late June and July. The aphid species *Aphis spiraecola,* (Figure 8) was assumed to be the most significant vector of PPV in PA due to its prevalence in orchards during the growing season and its efficiency as a vector.

Based on limited evidence supporting vector-mediated transmission of PPV in NY, aphid populations were not monitored or characterized for their vectoring capability.

Figure 8. Aphid, *Aphis spiraecola*, common vector of *Plum pox virus*. Courtesy of Fred Gildow, Penn State University.

VII. References: Educational Program Materials and Research Publications

Hardcopy publications, videos and dedicated web sites were developed soon after PPV was first discovered in PA and NY. Educational programs were developed to educate the US fruit producers of the threat of PPV to the *Prunus* fruit industry, aid in symptom recognition and promote communication among government agencies, university research and extension programs.

Educational Program Materials: Publications/Websites

- **Fact Sheet - Sharka: Plum Pox Virus of Stone Fruits:** Released in January 2000, three months after PPV was first identified in PA, this publication was the first grower educational literature on the disease. The fact sheet consisted of 4 color pages providing disease history, symptoms, fruit tree susceptibility, virus characterization, mechanism of spread and information on quarantine and eradication. A 2-page black and white insert was included which provided specific information on the identification, survey results, an indemnity program and plans for control in Pennsylvania (***Prepared by F. E. Gildow, J. W. Travis, J. Halbrendt, Penn State University and R. Welliver, PA Depart. of Agric***.).

- **Fact Sheet – Plum pox disease of stone fruits.** **http://nysipm.cornell.edu/factsheets/treefruit/diseases/pp/pp.pdf.** This 2-page fact sheet with color figures provides information on the biology of the disease, host range, impact, transmission and management. It was published in 2008. (***Prepared by M. Fuchs, R. Cox and K. Cox, Cornell University***).

- **Penn State University Extension PPV Web Sites:** **http://extension.psu.edu/plants/tree-fruit/diseases/sharka.** This web site was available by January 2000. It provided historical information of PPV and color images of symptoms from PA, Spain and France. There were also regular updates on the current status of the PPV eradication program. Growers from PA and across the United States regularly visited the site to stay informed on the status, plans and progress being made in the PPV eradication effort. Educational meetings being planned by extension and the PA Department of Agriculture were listed on the site. In the first six months there were 6,872 visits to the site. Many growers commented that this site was one of their primary sources of timely information on the disease (***Supported by J. W. Travis and C. Backman, Tara Baugher, Penn State University***).

- **PA Department of Agriculture PPV Web Site:** **http://www.agriculture.state.pa.us/portal/server.pt/gateway/PTARGS_0_2_24476_10297_0_43/http%3B/10.41.0.77/AgWebsite/ProgramDetail.aspx?name=Plum-Pox-Virus-Survey-and-Eradication-Program&navid=12&parentnavid=0&palid=126&.** Established within the first six months of the PPV eradication effort in PA this site provided information

on the specifics of current eradication efforts, indemnification programs and informational meetings being organized to provide growers and other interested parties with contacts to state and federal agency representatives. Growers accessed the site on a regular basis to remain informed of the eradication and indemnification programs (***Supported by N. Richwine, R. Welliver, K. Valley, PA Dept of Agric.***).

- **Cornell University PPV Web Site:** **http://web.pppmb.cals.cornell.edu/fuchs/ppv/.** This site provides information on the disease, laboratory-based detection techniques, management strategies, maps showing NY Counties dealing with PPV, and other links of interest (***Supported by M. Fuchs, Cornell University, Department of Plant Pathology***).

- **NY State Department of Agriculture and Markets PPV Web Site:** **http://www.agriculture.ny.gov/PI/ppv/ppv.html.** This site provides information on the disease, past and on-going eradication efforts in commercial orchards and homeowner properties, maps of quarantine and regulated areas and other useful links to technical and regulatory information (***Supported by the New York State Department of Agriculture and Markets***).

- **USDA Plum Pox Fact Sheet:** Produced by the USDA in 2000, the fact sheet provides information on history, symptoms, spread and control along with contact information to report infestations (***Supported by USDA-APHIS-PPQ and USDA-ARS personnel***).

- **Video: Plum Pox Virus in Pennsylvania, April 2000:** The 42 min video was released in April 2000 and was distributed to extension educators, fruit researchers and fruit grower organizations across the United States. It was used as an educational tool that provided a history of the disease and symptoms but also the personal accounts of the PA farmers who were most affected by the disease. Researchers, state regulators and extension personnel were also interviewed to provide information on research, survey methods, quarantines and extension educational programs being established to eradicate the disease (***Content Authors: J. W. Travis and F. E. Gildow; J. Harper Producer: J. Dickison; Editor: T. Cherry, Penn State University Extension***).

- **Plum Pox Virus and Other Diseases of Stone Fruits: A Field Guide.** This pocket field guide is 120 pages of color images of PPV symptoms on fruit, leaves and seeds from PA and Europe. It provides explanation of where to look and how to find symptoms. The guide also provides color images of the differing PPV symptoms between the stone fruits such as peaches, apricots and plums. There was much concern in the fruit grower community about any marks or abnormal symptoms on stone fruits. It was soon realized that although growers had fact sheets and web sites with symptoms to refer to when evaluating symptoms on the fruit, they had no field-ready guide to easily carry with them to examine and compare symptoms of PPV in the orchard. This pocket guide to PPV and other

stone fruit disease symptoms was developed by the second growing season after PPV had first been identified and was used widely by growers and extension educators in orchards (***Developed by J. W. Travis, F. E. Gildow, K. D. Hickey, D. Sammataro, J. Rytter, G. Krawczyk, R. M. Crassweller, R. A. Welliver and N. S. H. Richwine from Penn State University and the PA Department of Agriculture***).

- **Poster of Plum Pox Virus Symptoms on Stone Fruits.** The poster displayed color images of PPV on fruit and leaves and was produced in English and Spanish. It was developed for grower use in education of the public and their orchard workers (***Developed by the California Department of Food and Agriculture and USDA personnel***).

Supporting Research and Publications

Research has been conducted to address some of the key questions regarding PPV spread, insect vectors, virus characterization, genetic variability of virus isolates, and host susceptibility. The following is a list of some of the research manuscripts published in support of the PPV eradication program in the USA:

Alter, T.R., Bridger, J.C. and Travis, J.W. 2004. Robust Research and Rapid Response: The Plum Pox Virus Story. Journal of Higher Education Outreach and Engagement 9:131- 140.

Barba, M., Hadidi, A., Candresse, T. and Cambra, M. 2011. *Plum pox virus*. In: Virus and Virus-like Disease of Pome and Stone Fruits, Hadidi, A., Barba, M. aCandresse, T and Jelkmann, W (eds), pp. 185-197, St Paul, MN, APS Press.

Cambra, M., Capote, N., Myrta, A. and Llaàcer, G. 2006. *Plum pox virus* and the estimated costs associated with sharka disease. EPPO Bulletin 36:202-204.

Chirkov, S. Peter Ivanov, P., and Sheveleva, A. 2013. Detection and partial molecular characterization of atypical plum pox virus isolates from naturally infected sour cherry. Archives of Virology 158:1383-1387.

Damsteegt, V.D., Stone, A.L. and Luster, D.G. 2001. Preliminary characterization of a North American isolate of *Plum pox virus* from naturally infected peach and plum orchards in Pennsylvania, USA. Acta Hort 550:145-152.

Damsteegt, V.D., Stone, A.L., Schneider, W., Luster, D.G. and Gildow, F.E. 2004. Potential *Prunus* host range of PPV-PENN isolates by aphid transmission. Acta Hortic. 657:201-205.

Damsteegt, V.D., Stone, A.L., Sherman, D.J., Schneider, W.L., Gildow, F., Luster, D.G. 2005. *In planta* interactions of three plum pox potyvirus strains within cultivar Lovell peach seedlings. Phytopathology 95:s22.

Damsteegt, V.D., Scorza, R., Stone, A.L., Schneider, W.L., Webb, K., Demuth, M. and Gildow, F.E. 2007. *Prunus* host range of *Plum pox virus* (PPV) in the United States by aphid and graft inoculation. Plant Disease 91:18-23.

Garcia, J.A., Glasa, M., Cambra, M. and Candresse, T. 2014. *Plum pox virus* and sharka: a model potyvirus and a major disease. Molecular Plant Pathology 15:226-241.

Gildow, F.E., Damsteegt, V., Stone, A., Schneider, W., Luster, D. and Levy, L. 2004. Plum pox in North America: Identification of aphid vectors and a potential role for fruit virus spread. Phytopathology 94:868-874.

Glasa, M., Prikhodko, Y., Predajna, L., Nagyova, A., Shneyder, Y., Zhivaeva, T., Subr, Z., Cambra, M. and Candresse, T. 2013. Characterization of sour cherry isolates of *Plum pox virus* from the Volga basin in Russia reveals a new cherry strain of the virus. Phytopathology 103:972–979.

Gottwald, T.R., Wierenga, E., Luo, W., Parnell, S. 2013. Epidemiology of Plum pox 'D' strain in Canada and the USA. 2013. Canadian Journal of Plant Pathology 35:442-457.

Hily, J.M., Scorza, R., Malinowski, T., Zawadzka, B. and Ravelonandro, M. 2004. Stability of gene silencing-based resistance to *Plum pox virus* in transgenic plum (*Prunus domestica* L.) under field conditions. Transgenic Research 13:427-436.

Hughes, G., Gottwald, T.R., and Levy, L. 2002. The use of hierarchical sampling in the surveillance program for Plum pox virus incidence in the United States. Plant Disease 86:259-263.

James, D., Varga, A. and Sanderson, D. 2013. Genetic diversity of *Plum pox virus*: strains, disease and related challenges for control. Canadian Journal of Plant Pathology 35:432-441.

Levy, L., Damsteegt, V. and Welliver, R. 2000. First report of *Plum pox virus* (Sharka disease) in *Prunus persica* in the United States. Plant Disease 84:202.

Mavrodieva, V., James, D., Williams, K., Negi, S., Varga, A., Mock, R. and Levy, L 2013. Molecular analysis of a *Plum pox virus* W isolate in plum germplasm hand carried into the USA from the Ukraine shows a close relationship to a Latvian isolate. Plant Disease 97:44-52.

Palmisano, F., Boscia, D., Minafra, A., Myrta, A and Candresse, T. 2012. An atypical Alabanian isolate of Plum pox virus could be the progenitor of the Marcus strain. In: 22nd International Conference on Virus and Other Graft Transmissible Diseases of Fruit Crops, June 3-8, Rome, Italy, Book of Abstract, p.33.

Ravelonandro, M., Scorza, R., Bachelier, J.C., Labonne, G., Levy, L., Damsteegt, V., Callahan, A.M. and Dunez, J. 1997. Resistance of transgenic *Prunus domestica* to plum pox virus infection. Plant Disease 81:1231-1235.

Scorza, R., Callahan, A., Ravelonandro, M. and Braverman, M. 2013. Development and Regulation of the Plum Pox Virus Resistant Transgenic Plum 'HoneySweet'. In: C. A. Wozniak and A. McHughen (eds.), Regulation of Agricultural Biotechnology: The United States and Canada, Springer, Dordrecht, pp 269-280.

Schneider, W.L., Sherman, D.J., Stone, A.L., Damsteegt, V.D., Frederick, R.D. 2004. Specific detection and quantification of *Plum pox virus* by real-time fluorescent reverse transcription-PCR. Journal of Virological Methods 120: 97-105.

Schneider, W.L., Damsteegt, V.D., Gildow, F.E., Stone, A.L., Sherman, D.J., Levy, L.E., Mavrodieva, V., Richewine, N, Welliver, R. and Lister D.G. 2011. Molecular, ultrastructural and biological characterization of Pennsylvania Isolates of *Plum pox virus*. Phytopathology 101:627-636.

Snover-Clift, K.L., Clement, P.A., Jablonski, R., Mungari, R.J., Mavrodieva, V.A., Negi, S. and Levy, L. 2007. First report of *Plum pox virus* on plum in New York State. Plant Disease 91:1512.

Theilmann, J., Yang, L. and Rochon, D. 2006. Sequence analysis of isolates of the Canadian *Plum pox virus*, and comparisons to isolates from Europe and the United States. Canadian Journal of Plant Pathology 35:144-151.

Wallis, C.M., Fleischer, S.J., Luster, D. and Gildow, F.E. 2005. Aphid (Hemiptera: Aphididae) species composition and potential aphid vectors of *Plum pox virus* in Pennsylvania peach orchards. Journal of Economical Entomology 98: 1441-1450.

Wallis, C. 2004. Aphid vectors and viral microevolution of Pennsylvanian strains of plum pox virus. M.S. thesis, The Pennsylvania State University, University Park, PA.

Wallis, C.M., Stone, A.L., Sherman, D.J., Damsteegt, V.D., Gildow, F.E. and Schneider, W.L. 2007. Adaptation of *Plum pox virus* to a herbaceous host (*Pisum sativum*) following serial passages. Journal of General Virology 88:2839-2845.

NE 1006 Multi-State Program on Plum Pox Eradication and Control

This project was developed to promote communication and collaboration between university researchers and extension educators, government agency personnel and international cooperators. The meetings were held yearly and focused on research, education and the eradication efforts taking place in the United States and Canada.

VIII. Fruit Grower Observations and Recommendations

Regular meetings with stone fruit industry representatives, including growers and nurseries, extension educators, and state and federal regulators in Pennsylvania and New York have facilitated communication and the coordination of efforts in support of eradication programs.

In Pennsylvania, there was an informal meeting of the growers who were most affected by the PPV eradication program in May 2006 to discuss their view of the PPV eradication project. These growers included the grower and his brother who first observed PPV in their orchard and the grower who was the president of the PA stone fruit grower organization when PPV was first identified as a problem. Both growers lost all of their peach, nectarine and apricot orchards totaling nearly 500 acres. At the time of the meeting, neither grower was permitted to replant any stone fruits on their farm since the eradication began nearly seven years earlier. The discussion was facilitated by a local extension educator and a state extension specialist, who had worked along side the growers since the beginning of the PPV eradication program.

The growers were in agreement that the PDA, USDA and Penn State University personnel they interacted with over the course of the PPV eradication effort had been responsive and supportive. There was particularly high praise for the efforts of the PDA and Penn State extension for the dedication of time and effort extended on their behalf as the PPV situation unfolded in 1999 and 2000. There was good communication at the onset of the PPV eradication program and regular communication continued as the program advanced to keep them informed and involved in the process. The regular communication meetings between growers, government regulators, legislators and extension have been appreciated by the fruit grower community.

The growers agreed that new science based information developed by PSU and USDA scientists have provided answers to some important questions regarding spread and containment of PPV. Quarantine and eradication decisions made by PDA and the USDA have been based on the best science available. The support of PSU agriculture economists in working with the USDA to develop the indemnity program and the financial support provided through local legislators and PDA were instrumental in assuring grower cooperation and the ultimate success of the PPV eradication program.

In New York, the NY State Department of Agriculture and Markets has convened a PPV working group, consisting of representatives of the grower community and researchers, and organized regular meetings with local growers. It also reached out to grower groups during winter conventions and twilight meetings. These meetings provided unique opportunities to discuss eradication progress, prospects for deregulating regulated areas and planting options, as well as concerns.

Grower Concerns and Recommendations:

1. The grower community has raised concerns about the substantial reductions in funding by the federal government in recent years and prior to successful completion of the PPV eradication program. This will make useless the growers' sacrifice and may undermine PPV eradication efforts that have taken place to date.

Recommendation: The federal and state governments should approve adequate funding to complete PPV eradication in a timely manner.

2. The spatial proximity of PPV-infected stone fruit trees in Ontario, Canada represents a serious threat to the NY industry. This threat is worsened by the fact that Canada transitioned from a so-called eradication to a so-called monitoring program. If due diligence is not done immediately, the PPV eradication program in NY, even if successfully completed in the near future, will be seriously jeopardized.

Recommendation: Call for due diligence in terms of the implementation of NAPPO standards and the removal of all PPV-infected trees in Canada, and put in place long-term funding mechanisms to deal with the possibility of a catastrophic re-introduction event.

3. Growers with orchards located in a quarantine zone but who did not have their orchard removed have suffered the most. They have not been permitted to follow normal production practices such as replanting to maintain full orchard productivity.

Recommendation: Allow growers to replant in existing orchards in a quarantine zone with planting material derived from virus-tested certified stocks to maintain orchard productivity.

4. The growers' input seems to have been initially taken into account in the decision-making process but as time has gone on their concerns have been progressively ignored.

Recommendation: Incorporate the growers back into the decision-making process so that the industry priorities are considered.

5. The role of the National Clean Plant Network (NCPN) in the identification of virus-

tested, clean foundation stocks is crucial to the stone fruit industry.

Recommendation: Enhance NCPN to expedite even more the availability of clean, certified planting material and revise certification standards to accelerate the production of clean stocks.

6. Limited clean, certified material is available to the stone fruit industry.

Recommendation: Make flexible quarantine and laboratory space available for overflow/surge testing capacity at a regional level, maybe through NCPN.

7. There is little transparency on survey efforts at the national level.

Recommendation: Augment the quality of communication by USDA-APHIS-PPQ as well as their accountability to the U.S. stone fruit industry.

8. Limited information is available on the genetic relationship between PPV strains found in the US, in particular in NY, and in Canada as well as in other countries.

Recommendation: Assemble a team of scientists to address the relationship among PPV strains in order to advance our understanding of disease outbreaks and spread, providing opportunities to prevent future outbreaks.

IX. Mitigation and Disease Management

Prevention

It is important to prevent the introduction and dissemination of PPV in propagation material. This is accomplished through the use by nurseries of virus-indexed plant material that is certified. The US Department of Agriculture, state departments of agriculture, and centers of the National Clean Plant Network utilize laboratory procedures to test for several viruses including PPV and certify that the stone fruit plant material can be used by nurseries for propagation and grafting.

While importation of nursery material into the United States is regulated, risks of introductions of PPV or other serious viral diseases of stone fruits remain. In addition, any screening of domestic stock is currently voluntary. Programs to monitor domestic material, in the event that an introduction occurs, is critical and is presently very limited or not provided for beyond the emergency/eradication program.

Exclusion/Eradication

Exclusion/eradication is the appropriate response to the discovery of PPV in commercial orchards, residential properties and areas where wild *Prunus* host species are grown.

Management

Management of PPV will become necessary if prevention and exclusion/eradication

efforts fail due to the spread of the disease in stone fruit orchards or native wild *Prunus* hosts. If the disease becomes established in stone fruit trees it will be managed through regular orchard surveys and tree removal if individual trees are infected. Surveys should be conducted in the spring when virus titer is usually high. Tissue samples may also be collected at this time to verify PPV infection using laboratory analysis. Individual trees will be removed when only a few trees are infected in an orchard. Orchard removal will occur once significant numbers of the trees in an orchard are infected with PPV. For example, one PPV management program in Europe removes the entire orchard if more than 10% of the trees are infected with PPV.

Aphid management through the use of insecticides is not expected to be effective in reducing the spread of PPV in stone fruit orchards. Aphids that visit a healthy stone fruit tree can transmit PPV to the tree through feeding before the insecticide affects the aphid. Tree removal begins with cutting of infected trees in the orchard. Some specialists suggest that applying an insecticide to the infected stone fruit tree a day or two prior to cutting may prevent aphids from spreading the virus as they fly from the wilting infected tree to healthy trees in the orchard.

Weeds have not been found to serve as hosts for PPV. It will be important to eliminate native stone fruit trees near commercial stone fruit orchards.

Genetically Resistant Cultivars

Genetic resistance to PPV has been identified and transferred to "HoneySweet" plum through RNA interference. The plum was developed at USDA-ARS in Kearneysville, WV. This is the first stone fruit cultivar developed for resistance to PPV. The USDA-ARS petitioned the USDA Animal and Plant Health Inspection Service, the Environmental Protection Agency and the Food and Drug Administration to deregulate the "HoneySweet" plum. The fruit yield, quality and market value under a range of growing and cultural conditions remains to be determined. Stone fruit cultivars resistant to PPV hold the most promise in managing PPV in the future if eradication efforts fail. The "HoneySweet" plum is not yet available for commercial use.

X. Research and Extension Priorities

Below are a few priorities that should be considered to help accelerate the success of ongoing eradication efforts in NY and prevent further hardships not only to the NY but also to the US stone fruit industry with regard to PPV in case of either PPV re-introduction from Canada or other sources, or introduction of other high consequence diseases in the future.

1. New detection reagents and technologies should be validated to be certain that the most sensitive and specific detection tools and methodologies are being used in the eradication program and in future monitoring schemes. In addition, a proactive approach should be taken to identify and develop monitoring strategies for other exotic pests that have economic impacts on the same scale as PPV.

2. A stronger *Prunus* industry would emerge from the PPV crisis across the country if steps were taken to prevent introduction of such a pest or other undesired pathogens again. Stakeholders need to look at existing nursery importation, clean stock, and certification structures and schemes, and improve them where necessary.

3. Initiatives to maintain a strong political will for continued funding of intensive long-term surveys along the Niagara River and of baseline surveys across the US should be considered to capitalize on on-going eradication efforts.

4. National extension efforts to raise awareness on the economic impact of PPV and enhance best management practices such as the removal of nursery production from fruit production areas and proper disposal of culls, among others, should be considered.

5. Risk assessment studies should be conducted to predict the movement of different strains of PPV in North America, even in Western U.S. States from British Columbia, knowing their present or past occurrence in Ontario and Nova Scotia.