WASHINGTON STATE UNIVERSITY EXTENSION

PROACTIVE APPROACHES FOR CONTROLLING RECOMBINANT *POTATO VIRUS Y* STRAINS IN WESTERN WASHINGTON

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TB49E Alternative Sources of *Potato virus Y* in Western Washington

FS312E *Potato virus Y* and Organic Potatoes in Western Washington

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FS313E

PROACTIVE APPROACHES FOR CONTROLLING RECOMBINANT *POTATO VIRUS Y* STRAINS IN WESTERN WASHINGTON

By

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Abstract

Recombinant strains of *Potato virus Y* (PVY) were detected in western Washington for the first time in 2012 and 2013. Recombinants can arise naturally when two or more different virus strains co-infect a plant cell. The presence of recombinant strains of PVY in the region is troubling because these strains are sometimes able to infect potato plants without causing obvious foliar symptoms, thus, making visual recognition of infected plants unreliable and thereby confounding seed potato certification efforts. This publication describes research investigations that were designed to answer frequent questions about three PVY strains: O, NTN, and N-Wi, and provides suggestions on proactive measures that can be taken to mitigate both seed tuber-borne and current season PVY infections.

Introduction

The potato industry in western Washington depends on the production of high-quality specialty potatoes, such as thin-skinned red, purple, yellow, and fingerling cultivars. These potatoes have strong consumer appeal and are well suited to the region's maritime climate. They are grown aggregately on 2,572 acres, mainly as either seed tubers in Whatcom Co. with a $7.3 million farmgate value in 2017 (Washington State Seed Potato Commission 2017; C. Benedict, personal communication), or commercial ware potatoes in Skagit and Snohomish Co. with an estimated total of 12,000 acres at a $60 million farmgate value in 2016 (D. McMoran, personal communication). Loss of potato tuber quality poses a serious economic threat to these counties and to locations where western Washington seed-potato tubers are exported or sold in the marketplace.

The "ordinary" strain of *Potato virus Y* (PVY^{O}) is one of the oldest known plant viruses and causes foliar symptoms of mosaic, mottle, veinal necrosis, and leaf drop, as well as serious losses in tuber yield and quality. In the 2000s, novel recombinant strains of PVY were reported in many potato-growing areas of the U.S. (Crosslin et al. 2006; Piche et al. 2004) and two of these strains, PVY^{NTN} ("tuber necrotic" strain) and $PVY^{N\text{-}Wi}$ ("necrotic Wilga" strain) were identified in western Washington in 2012 and 2013 (Benedict et al. 2015). The presence of these new strains is troubling, because the strains may infect potato plants without causing obvious foliar symptoms and, thus, have made visual diagnoses undependable (Karasev and Gray 2013). Until about 2016, Washington's seed potato certification program relied almost exclusively on visual observations for detecting PVY infections.

One very important aspect of PVY outbreaks is the ability of the virus to be transmitted in two ways: (i) through infected potato tubers i.e., "seed tuber-borne infections" and (ii) by aphid vectors. Tuber-borne infections occur when the virus moves from an infected plant into a developing tuber. The next potato generation is then at risk for tuber-borne PVY infection, if those tubers are planted as seed potatoes or develop into volunteer plants. To help minimize seed tuber-borne infections, seed potato certification programs have been in place in the U.S. for decades (Gray et al. 2010) and involve both field inspections and winter grow-out tests of seed potato lots, per various state guidelines. For a summary of Washington's seed potato certification rules see Washington State Legislature, Chapter 16-520 WAC.

PVY can also be transmitted by aphid vectors, or by any means in which infected plant sap is introduced into a plant, such as through wounds made by contaminated workers, tools, or equipment. Usually, these types of transmissions are referred to as "current season infections." Numerous species of aphids are known to vector PVY, and they can move PVY from infected plants, volunteer potatoes or weedy hosts, to, and throughout, commercial potato plantings. Aphids exhibit both wingless and winged forms: wingless forms can be blown by the wind while winged forms can fly to plants. Both forms transmit the ordinary and recombinant strains of PVY in a "non-persistent" manner, meaning that aphid vectors acquire particles of the virus on their needle-like mouth parts, called stylets, in only seconds or minutes and then remain infective afterwards for only brief periods of minutes to hours. The majority of aphids do not need to colonize potato plants in order to transmit the virus (Ragsdale et al. 2008). Colonizing aphids, or those that feed and then reproduce on potato plants, are the most efficient vectors of PVY. Non-colonizing aphids that move through potato fields and occasionally feed on potato plants transmit PVY less efficiently.

Both seed tuber-borne and current-season infections can be caused by recombinant strains of PVY. Although visual symptoms and common serological tests, like Agdia ImmunoStrips (Elkhart IN) and/or ELISA, are very important for PVY identification and confirmation, they are not sufficient for differentiating among PVY strains. If the time of sampling is towards the end of the growing season, these serological tests also can result in inaccurate testing (Beissinger and Inglis 2018). Further, certain strains of PVY express symptoms differently on different potato cultivars. For a photographic key to foliar symptoms of mosaic (Figure 1), mottle, veinal necrosis, and leaf drop on ten selected specialty potato cultivars as caused by PVY strains O, NTN, and N-Wi, see WSU TB49E by Beissinger et al., 2018. Recently, an association between potato tubers with suberized, canoe-shaped cracks and $PVY^{N\text{-}Wi}$ (Figure 2) was demonstrated (Benedict et al. 2015; Inglis 2016). These cracks present a serious problem to seed potato growers because of possible PVY transmission ability and to fresh market potato growers because of reduced tuber quality and marketability. In addition to cultivar reactions, symptom expression by PVY on both potato foliage and tubers may be affected by fertilization, irrigation, crop production practices, and climatic conditions.

Figure 1. A potato plant with classic symptoms of mosaic caused by *Potato virus Y* (photo courtesy of B. Gundersen).

Figure 2. Potato tubers with malformations, necrosis, and shallow, suberized cracks caused by *Potato virus Y* (photo courtesy of B. Gundersen).

Planting certified seed potatoes, managing volunteer potato plants and weedy hosts, and destroying refuse potato piles are essential PVY control practices (Crosslin et al. 2008). However, to address the implications of recombinant strains of PVY newly present in western Washington and uncertainty about how they can be managed, additional proactive approaches to PVY management were investigated. This publication reports on those studies and is divided into two parts:

I. Minimizing seed tuber-borne PVY infections by studying virus transmission to tubers, and

II. Reducing current-season PVY infections via aphid vectors by using barrier cover crops as stylet cleaning-sites.

I. Minimizing Seed Tuber-Borne PVY Transmissions.

Potato tubers play an important role in the transmission and spread of PVY. Although transmission rates are generally quite low in certified early generation seed lots, even a low transmission ability initially can have an impact. Consider one acre of potatoes where rows are 36 inches apart, the plants are spaced at 8 inches within the row, and there is a 0.10% transmission rate. That would make for 21,780 plants per acre multiplied by 0.001 for 21.8 potentially infected plants per acre. If the potato field is 50 acres, then there could be 1,090 infected plants. While these numbers are merely speculative and do not take into account the many other factors that influence PVY disease establishment, they do illustrate the value of seed potato certification programs and the critical importance of minimizing seed tuber-borne infections. Moreover, PVY incidence can increase with each subsequent seed potato generation when such infections are left unchecked.

There is not a lot of information about whether new recombinant strains of PVY affect seed potato transmission of the virus, although studies on aphid transmission rates have been done with different strains of PVY (Mello et al. 2011; Verbeek et al. 2010). Thus, a series of experiments were carried out to determine whether: (A) recombinant strains of PVY can be transmitted to progeny tubers naturally in the field; as well as (B) during seed potato cutting operations; (C) if recombinant PVY strains differ in their ability to be transmitted via seed tubers; and whether (D) tuber cracking is more likely to occur with seed tuber-borne rather than current-season infected plants.

A. Transmission of recombinant strains of PVY from field-grown plants to progeny tubers.

Potato plants of “Chieftain” growing in an experimental field trial at WSU Mount Vernon NWREC in 2013 displayed either no symptoms, moderate, or severe mosaic symptoms of PVY, caused by a combination of PVY^{O}, PVY^{NTN}, and/or $PVY^{N\text{-}Wi}$. Selected plants were flagged according to symptom severity, tracked over the growing season, and tested near the time of vine kill for PVY using Agdia ImmunoStrip test kits. Harvested tubers were carefully sorted by symptom type and stored separately at 38°F over the winter. When 20 seed tubers from plants in each of the three symptom categories (no symptoms, moderate, or severe mosaic) were planted in a greenhouse grow-out test in early spring 2014, almost all (53 of 60 or 88.3%) were positive for PVY. All plants grown-out from seed tubers of moderate and severe category field plants (40 in total) were symptomatic and tested PVY positive. However, 13 of the 20 greenhouse plants grown-out from seed tubers of field plants that had shown no symptoms, revealed virus symptoms and also tested PVY-positive. This finding illustrated that even asymptomatic plants with very low levels of virus can lead to seed tuber-borne PVY infections in later potato generations, and provided evidence on the importance of using field test kits for PVY detection early (before or at flowering) rather than late (after flowering) in the potato growing season.

B. Transmission of recombinant strains of PVY during seed potato tuber cutting.

In a series of greenhouse experiments, 'Chieftain' potato and White Burley tobacco plants were discretely inoculated with PVY^{O}, PVY^{NTN}, or $PVY^{N\text{-}Wi}$. Potato slurry or tobacco sap from infected tubers or leaves, respectively, then was used as inoculum to determine whether PVY can be transmitted during a seed potato cutting operation (Figure 3). PVY-infected slurry or sap was spread onto a sterile knife before cutting nuclear (virus-free) seed tubers of 'Chieftain' (Valley Tissue Culture, Halstad, MN) in half, from the apical to stem end. Cut seed tubers were planted in 1-gallon pots in potting media and kept in a greenhouse at 65°F with a 16:8 light:dark cycle. To prevent cross-contamination between PVY strains throughout the experimental set-ups, care was taken to change gloves, dip knives and cutting boards in 10% bleach solution, and segregate plants on greenhouse benches by strain. Also, nylon screens and a limited access policy was employed to prevent aphid entry into greenhouse bays. Plants were rated visually for virus symptoms on a regular basis and tested for PVY by Agdia ImmunoStrips or ELISA after flowering. Transmission rates across seven experiments ranged from 2.1 to 25% (Table 1) for the three PVY strains. Clearly, when knives and cut tuber surfaces become contaminated during commercial seed cutting operations, transmission of any one of the three PVY strains can take place and lead to seed tuber-borne PVY infections.

Figure 3. Cutting through a virus-free nuclear tuber of 'Chieftain', with a sterile knife contaminated with sap of *Potato virus Y* (photo courtesy of B. Gundersen).

Table 1. *Potato virus Y* transmission rates as a result of cutting seed tubers with a contaminated knife.

Study	PVY source[a]	Inoculation method for recipient virus-free nuclear seed tuber or plant	No. plants in study	No. grow-out plants PVY positive				Total grow-out plants confirmed infected (excluding controls)
				O	NTN	N-Wi	Water control	
Year 2014								
GH-2	Slurry from infected seed potato tuber.	Cutting after contaminating a sterile knife.	20	*nt*[b]	*nt*	5/20	---	25%
	Slurry from infected seed potato tuber.	Tumbling with infected seed potato tuber.	20	*nt*	*nt*	0	---	0%
	Infected potato plants, each with obvious mosaic.	Infected plants touching healthy plants.	20	*nt*	*nt*	0	---	0%
	Control (nuclear seed tubers cut with a virus-free knife)		4	---	---	---	0	0%
Year 2015								
GH-8	Slurry from infected seed potato tuber	Cutting after contaminating a sterile knife	48	0	1/12	0	0	2.8% (1/36)
GH-9	Slurry from sprout or necrotic tissue of infected seed potato tuber	Cutting after contaminating a sterile knife	20	*nt*	*nt*	1/5	0	20%
GH-10	Slurry from infected seed potato tuber	Cutting after contaminating a sterile knife	64	0	0	1/16	0	2.1% (1/48)
GH-11	Slurry from infected seed potato tuber	Serial cutting with a contaminated knife through 8 consecutive recipient tubers	64	*nt*	*nt*	1/16[c]	0	2.1% (1/48)
GH-12	Slurry from infected seed tuber slurry or potato leaf sap	Cutting after contaminating the knife	96	0	1/24 (sap)	2/24 (slurry and sap)	0	4.2% (3/72)
Year 2016								
GH-3	Slurry from infected seed potato tuber or infected tobacco plant sap	Cutting after contaminating the knife	168	2/42 (slurry and sap)	4/42 (sap)	4/42 (slurry and sap)	0	7.9% (10/126)

[a] All experiments used virus-free nuclear seed of 'Chieftain', four-to-six replications of one-to-eight plants per replication, and a randomized complete block experimental design for pots on greenhouse benches. PVY strains were provided by A. Karasev and maintained discretely on White Burley tobacco following standard virology techniques.

[b] nt = not tested

[c] Plant from recipient tuber #4 in the serial inoculation, confirmed infected with PVY.

C. Differential ability of the PVY strains to be transmitted via infected seed tubers.

Experiment 1. Virus-free tissue culture plantlets of ‘All Blue’, ‘Chieftain’, ‘French Fingerling’, ‘Russet Burbank’ and ‘Yukon Gold’ were obtained from the Nuclear Seed Potato program at the University of Idaho. Four weeks after transplanting, plants were mechanically inoculated using the sap of tobacco leaves confirmed to be infected with each of the three PVY strains. The inoculation procedure involved grinding leaves in cold buffer (500 ml deionized water, 6.7 g Na_2HPO_4, 3.3 g KH_2PO_4) at a ratio of 1:10 (w/v) within a sterile, cold mortar and pestle, then gently rubbing the mixture onto potato leaves following a light dusting with Carborundum (silicon carbide). All inoculated potato leaves were rinsed with a stream of deionized water to remove excess homogenate, and care was taken to avoid cross-contamination between PVY strains. Plants were maintained in a greenhouse kept free of aphids, placed on benches by strain (Figure 4), observed weekly for symptom development until senescence, and tested at various time points for PVY. Tubers from PVY positive plants were harvested and stored at 38°F over the winter, then grown-out the following spring in the greenhouse. Although the total number of grow-out plants was low (n=20), transmission rates were high for all three strains: 2 of 2 (100%) positive for PVY^{O}, 8 of 13 (61.5% positive) for PVY^{NTN}, and 5 of 5 (100%) positive for $PVY^{N\text{-}Wi}$ across the five cultivars.

Figure 4. Potato plants inoculated with *Potato virus Y* in a greenhouse test. Following confirmation of PVY, harvested tubers were stored over the winter and grown out in the spring to ascertain the number of seed tuber-borne infections (photo courtesy of B. Gundersen).

Experiment 2. The same five cultivars were grown from virus-free nuclear seed tubers (instead of tissue-culture plantlets as above) and the foliage was again sap inoculated with the three PVY strains, but in a larger-scale factorial experiment in the greenhouse. The same inoculation and sanitation methods and growing conditions were used as explained above. Tubers collected from infected plants and stored over the winter for a spring grow-out test transmitted PVY at percentages (Figure 5), ranging from 42 to 100%. There was no difference in transmission ability among the three PVY strains with the exception of minimal transmission of PVY^{NTN} on Yukon Gold.

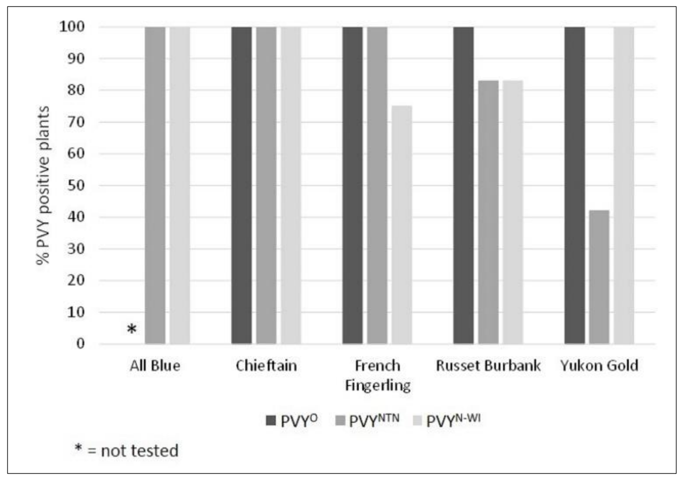

Figure 5. Transmission percentages of *Potato virus Y* in study of next generation seed tubers acquired from nuclear seed potato plants mechanically inoculated with strains O, NTN, and N-Wi.

D. Occurrence of tuber cracking in seed tuber-borne versus current season PVY infections.

Experiment 1. A field study was planted at WSU Mount Vernon NWREC in 2015 using cracked seed tubers from $PVY^{N\text{-}Wi}$-infected ‘Chieftain’ plants and virus-free nuclear seed tubers of ‘Chieftain.’ The two treatments were replicated four times, and planted to ten, 2–3 ounce seed tubers using a 9-inch seed spacing and 38-inch row spacing.

Destructive sampling of two plants per treatment/replication combination at five seasonal time points revealed cracked tubers at 63 days after planting (DAP), the earliest sample date (Figure 6 and Figure 7) suggesting that tuber cracking initiated prior to tuber bulking. Seed tuber-borne PVY infections significantly reduced tuber yield in samples removed between 77 DAP and 91 DAP, which corresponded to the periods of tuber bulking and harvest. Furthermore, cracked progeny tuber average weight was significantly higher as a result of seed tuber-borne PVY compared to that of healthy progeny tubers grown from nuclear seed.

Figure 6. Cracking observed in progeny tubers from a $PVY^{N\text{-}Wi}$ infected plant during destructive sampling in the field (photo courtesy of B. Gundersen).

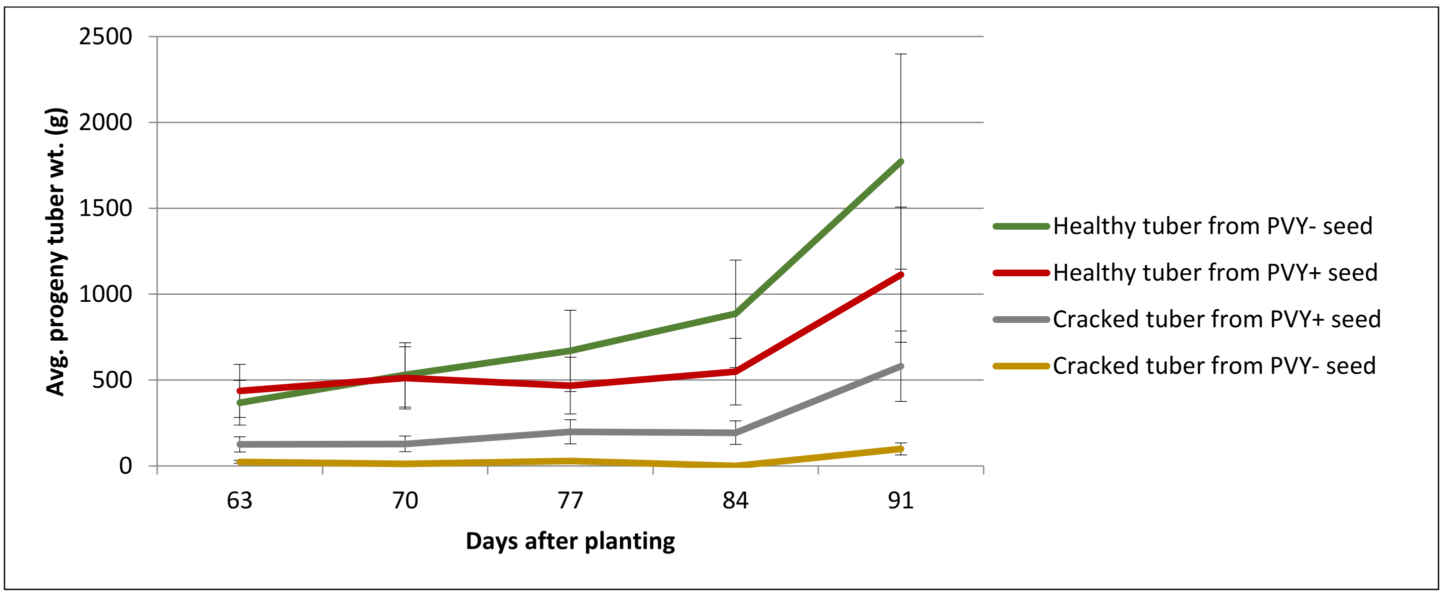

Figure 7.Average tuber weight at different time points as affected by planting seed tuber-borne *Potato virus Y* (PVY+) versus healthy (PVY-) nuclear seed.

Experiment 2. To further investigate the same question, but with the same five potato cultivars mentioned in Section C above, plants grown from nuclear seed tubers were inoculated with PVY^{O}, PVY^{NTN}, and $PVY^{N\text{-}Wi}$ in the greenhouse in 2016 using the above mentioned technique, and then confirmed to be PVY infected by ELISA. A greenhouse grow-out of saved tuber seed pieces from infected plants in 2017 produced surprising results (Table 2). Tuber cracking was not observed in ‘All Blue’, ‘Russet Burbank’, or ‘Yukon Gold’. However, progeny tubers from infected plants of ‘Chieftain’ had up to 28.3% of cracked tubers regardless of PVY strain, while tuber cracking was present even in the non-inoculated control plants of ‘French Fingerling’. Other observations on ‘French Fingerling’ have suggested that cracking in this cultivar often occurs in greenhouse settings and is not always virus-related. The yield of ‘Yukon Gold’ was dramatically reduced by using PVY infected seed tubers, especially those infected with PVY^{O}.

Table 2. *Potato virus Y* study on tuber cracking, using three PVY strains and five potato cultivars. All inoculated plants except for All Blue x PVY^{O} proved positive for PVY by ELISA.

Year 2017 GH-1	**PVY^{O}**					**PVY^{NTN}**				
Cultivar	Seed piece status[a]	Healthy tuber yield[b]	Cracked tuber yield	Total yield	Cracked (%)	Seed piece status	Healthy tuber yield	Cracked tuber yield	Total yield	Cracked tubers (%)
All Blue	3/12	433.7 a	0 a	433.7 a	0 a	1/12	368.3 a	0 a	368.3 a	0 a
Chieftain	0/12	197.4 c	82.8 b	280.2 b	28.3 b	2/12	303.0 a	35.8 b	338.8 a	10.4 b
French Fingerling	5/12	256.6 b	17.5 a	274.1 b	5.8 a	9/12	294.1 ab	16.9 ab	311.0 a	5.2 ab
Russet Burbank	0/12	243.6 b	0 a	243.6 c	0 a	0/12	371.1 a	0 a	371.1 a	0 a
Yukon Gold	1/12	2.9 d	0 a	2.9 d	0 a	0/12	220.7 b	0 a	220.7 b	0 a
LSD (P<0.05)		*38.80*	*36.70*	*28.04*	*11.61*		*78.61*	*23.13*	*77.21*	*6.82*
	$PVY^{N\text{-}Wi}$					**Water control**				
All Blue	0/12	393.6 a	0 a	393.6 a	0 a	0/12	334.4 a	0	334.4 ab	0
Chieftain	1/12	263.6 c	95.6 b	359.2 ab	26.3 b	0/12	344.4 a	0	344.4 ab	0
French Fingerling	3/12	343.7 ab	11.2 a	354.9 ab	7.4 a	2/12	346.9 a	11.8	358.7 a	3.5
Russet Burbank	0/12	345.9 ab	0 a	345.9 ab	0 a	0/12	282.2 b	0	282.2 c	0
Yukon Gold	0/12	309.7 bc	0 a	309.7 b	0 a	0/12	311.0 ab	0	311.0 bc	0
LSD (P<0.05)[c]		*64.24*	*39.20*	*50.03*	*12.28*		*45.57*	*NSD*	*43.10*	*NSD*

[a] Number of seed pieces that had canoe-shaped cracks, of 12 possible.

[b] All tuber yields are presented as g/plant.

[c] Data for each PVY strain analyzed separately; LSD = Least significant difference test; NSD = not significantly different.

Experiment 3. To ask the same question, and with later generation seed tubers, an experiment was set up at WSU Mount Vernon NWREC in 2016. Seed tuber-borne infections were obtained by planting cracked seed tubers of a G6 (Generation 6) seed lot of Chieftain known to be infected with $PVY^{N\text{-}Wi}$ while current season infections with $PVY^{N\text{-}Wi}$ were simulated by mechanically inoculating leaves of 4-week-old ‘Chieftain’ plants grown from virus-free nuclear seed. The same virus preparation and inoculation procedures were used as mentioned above. A screenhouse environment was chosen for the experiment to insure that there would be no current season transmissions that might arise from invading aphids. The two treatments were each planted to ten plants in four replications, using one-gallon pots and potting mix. Pots were arranged in a randomized complete block design. Stems were cut 93 days after planting, and tubers were harvested 120 days after planting. There was a much higher percentage (19.21% vs. 0.16%) of cracked tubers resulting from the G6 seedborne infections as compared to the current season infections (Table 3).

Table 3. Comparison of cracked tubers originating from current season versus seed tuber-borne *Potato virus Y* *N-Wi* infections.

Infection type[a]	**No. plants positive for PVY**[b]	**No. plants with cracked tubers**[c]	**Healthy tuber weight**[a]	**Cracked tuber weight**	**Total tuber weight**	**% Cracked tubers**
Current season	6/40	1/40	598 a	1	599 a	0.16
G6 seed tuber-borne	40/40	31/40	509 b	151	509 b	19.21
LSD (*P=0.05*)[d]	---	---	*42.7*	---	*22.9*	
Reference controls[e]						
Nuclear seed (PVY negative control)	0/10	0/10	575	0	575	0
G2 seed (PVY positive control	10/10	3/10	556	48	604	3.69

[a] Each infection treatment was replicated four times with 10 plants/replicate; G6 and G2 refer to seed potato generations 6 and 2, respectively.
[b] Positive by ELISA.
[c] All tuber yields are presented as g/plant.
[d] Means in a column followed by the same letter are not significantly different by LSD test.
[e] Not replicated.

II. Minimizing Current Season Aphid Transmissions.

Many insecticides used to control aphids have been shown to be ineffective in PVY management. Aphids transmit PVY very quickly and in a much shorter time than most insecticides often can act. Initially, aphids sprayed with insecticide become agitated and may move between plants to transmit the virus multiple times before being killed (Ragsdale et al. 2008). This, plus the fact that most PVY transmissions are by non-colonizing potato aphids, leads the control of PVY with insecticides to be poor at best (Pacific Northwest Pest Management Handbook). Mineral oil applications and certain insecticides can reduce some spread of PVY (MacKenzie et al. 2016), and some seed piece insecticides with systemic activity can contribute towards early- and mid-season aphid control. Insecticide effectiveness is based on active ingredients. For example, pyrethroids are known to flare aphids because of their negative impact on aphid predators and parasitoids. The Pacific Northwest Insect Management Handbook (Rinehold et al. 2017) outlines recommended aphid insecticide management options for the region. One thing that growers need to keep in mind regarding aphid control is that PVY has an extremely wide host range, including common crops like eggplant, pepper and tomato, and annual and biennial weeds like hairy nightshade, lambs quarters, pigweed, Shepherd's purse, and smartweed. Crops and weeds can serve as natural reservoirs for transmission of PVY by aphids from these hosts to potato plantings (Kaliciak and Syller 2009), and lead to repeated PVY introductions.

A. Reducing current season PVY infections with barrier cover crops.

Cover crops planted on field borders during the potato growing season have been used in combination with insecticides as an integrated approach for reducing current season PVY infections through crop barriers or "stylet cleaning-sites" for aphids (Groves and Frost 2012; Boiteau et al. 2008; Olson et al. 2006; Fereres 2000). Because PVY is non-persistently transmitted by aphids, an aphid that has acquired PVY can "clean" its stylet by probing the cover crop, thus depositing virus particles in the field border rather than the adjacent potato field.

On-farm trials were established in Whatcom County seed potato fields (five in 2015 and three in 2016) to evaluate three different single-stand cover crops and two-mixes of barrier cover crops (Table 4) for compatibility with a seed potato production system

(Figure 8). In each field at each farm, six-foot wide strips of each cover crop/mix were planted with a grain drill in three replications set up in a randomized complete block design. The crop barriers were monitored for aphids and the seed potato plants observed for PVY symptoms during the growing season. Tagged suspect plants later were tested for PVY by ELISA.

Spring oats proved the most attractive cover crop for winged aphids, which can choose where to land. However, sorghum x Sudan grass was the quickest to establish and had the highest cover crop biomass production (Table 4). Quick establishment and biomass is essential to providing an effective barrier. In 2015, aphids were present in the barrier crop at two sampling times, but not in the adjacent seed potato crop. In 2016 trials, yellow sticky card traps were placed at 15-foot increments, flying inward from field edges (starting at each major cardinal direction) to monitor for aphid movement inward within the field throughout the growing season. Spring oats proved to be the most attractive crop for winged aphids, and no non-colonizing aphids were detected during the growing season on any of the barrier crops or within the potato crop itself.

Figure 8. Spring planted oats adjacent to a seed potato field. The oats act as cleaning sites (barrier crop) for the stylets of *Potato virus Y* aphid vectors (photo courtesy of C. Benedict).

Table 4. Aphid barrier cover crop trial results in western Washington seed potato fields, 2016.

Cover crop	Seeding rate (lb/acre)	Biomass (dry weight as ton/acre) at vine kill, across 3 sites	Aphids (per one min of vacuuming), across three sites		
			June 15	July 15	August 1
Spring oats	100	2.8	68	42	83
Sorghum x Sudangrass	40	4.1	22	18	31
Spring oats + sorghum x Sudangrass	100 + 60 + 40	3.8	52	41	53
Spring oats + sorghum x Sudangrass	100 +80 + 20	3.2	59	36	86
Spring wheat	100	2.9	44	21	36

Overall, the seed potato fields that were surrounded with barrier crops showed little migration of aphids into field interiors. The aphid behavior could have been influenced by insecticide seed treatments and insecticide sprays applied in the established potato crop. However, no positive PVY foliar samples were obtained over the two years of the study. The lack of detection of PVY could have been due to the young age of the seed potato crop. Younger seed potato generations (nuclear and G1) likely are inherently compatible with barrier cover cropping because early generation crops are relatively virus-free initially, have high value so are worth the investment, and typically grown in smaller-size plantings where barrier crops are more effective because of less area.

Conclusions

Until 2012 (Benedict et al. 2015), western Washington was one of the last potato growing regions in the United States where recombinant strains of PVY had not been detected. Now, there are questions on how PVY management approaches can be improved to reduce incidence and spread, especially since not all potato cultivars have resistance to these strains (Funke et al. 2017). Certainly, the commonly recommended PVY management practices still apply (Crosslin et al. 2008; Nolte et al. 2009; Beissinger et al. 2018). But, additionally, this project has shown that very close attention needs to be given to eliminating seed tuber-borne PVY infections regardless of the PVY strain. Minimizing this transmission route also will help in minimizing subsequent current season infections by aphids and through other mechanical means.

Given the complexity of PVY infections and all three strains being transmitted via seed tuber propagation as well as during seed tuber cutting, organic potato growers (McMoran et al. 2018), seed potato, and commercial potato growers need to take direct steps in managing recombinant PVY strains. For instance, sanitizing knives and belts during seed cutting operations, especially when cutting seed potato pieces between different seed potato lots, is necessary. Producing or using certified early generation seed tubers also is a must. Planting seed tubers that are cracked is to be avoided, particularly if the cracks are shallow and canoe-shaped (Figures 2 and 6) as they present a greater risk for PVY infection

Because infections by recombinant strains of PVY sometimes lead to asymptomatic foliage (Beissinger et al. 2018), it is important to remember that even asymptomatic potato plants can produce infected seed tubers and lead to PVY spread. When this situation occurs in the next seed potato generation, rates of seed transmission can become high. Seed potato plantings should be randomly tested during early and/or mid-season field scouting activities (Beissinger and Inglis 2018) and then again during winter testing by using lateral flow devices such as Agdia ImmunoStrips and/or ELISA. Field rogueing operations need to involve removal and destruction of infected plants—not just pulling infected plants out of the ground since dying plants can be a source of PVY for aphids for several days (Boquel et al. 2017). Managing weedy hosts and aphid reservoirs and using aphid barrier crops on field borders also can be useful practices especially for early generation seed potato lots. Being aware of other potential alternative sources of PVY in a region also is highly recommended (Beissinger et al. 2018). Moreover, visiting seed potato fields during the summer and viewing winter test results before making a seed lot purchase to find out whether potato plants have been adequately scouted and tested is essential.

Acknowledgements

The authors thank Dr. Alexander Karasev and members of his laboratory for PVY isolates and PVY strain typing; and, Dr. Hanu Pappu and members of his laboratory for assisting with ELISA techniques. This research was made possible by the WSDA Specialty Crop Block Grant Program, Project K1509, and USDA AFRI Specialty Crops Research Initiative CAPS Project 2014-07878.

Additional Reading

Agdia ImmunoStrips and other products to test for PVY. https://orders.agdia.com/agdia-immunostrip-for-pvy-20001.

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