Epidemiology and Control of Aphid Transmitted Potato Viruses

Susan Halbert
Dennis Corsini
Larry Sandvol
Phillip Nolte

University of Idaho
College of Agriculture

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What is epidemiology?

The science of epidemiology of plant viruses is the study of the interactions between the plant, the pathogen (virus), and the vectors, which are insects and other organisms that move the virus from one plant to another. In the case of potato viruses discussed here, all vectors are aphids. Complex relationships have evolved that ensure propagation of potato viruses from season to season. An understanding of epidemiology is the first step in control of aphid transmitted potato viruses.

One of the most important aspects of epidemiology is the seasonal disease cycle. Initial infection of a field is called "primary spread." Primary sources of potato viruses can be infected seed or immigrating vectors that carry the virus from sources outside the field. Sources of virus outside fields are called reservoirs. Examples include infected potato crops, weeds, volunteer potatoes, or garden potatoes. Control of aphid transmitted viruses should be based on minimizing sources of virus (isolation from potential reservoirs, using virus free seed, and requiring elimination of virus in seed fields through roguing) and vector control to prevent spread from these sources.

Types of aphid transmitted potato viruses

The major aphid transmitted potato viruses in Idaho, potato leafroll virus (PLRV) (Fig. 1), potato virus Y (PVY) (Fig. 2), and potato virus A (PVA) (Fig. 3) fall into two basic categories of plant viruses, persistent and non-persistent, re-

Figure 1
Potato plant infected with potato leafroll virus [PLRV].

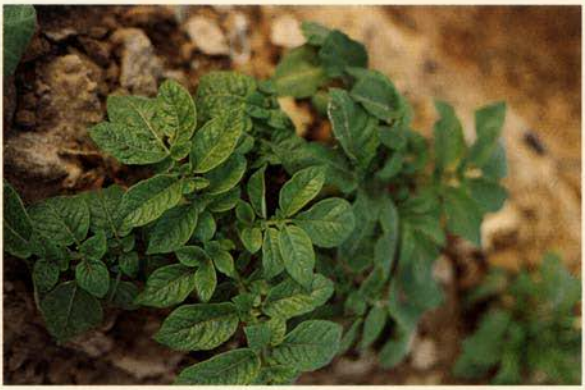


Figure 2
Potato plant infected with potato virus Y [PVY].

Figure 3
Potato plant infected with potato virus A [PVA].

ferring to their relationship to the aphid vector. The following table summarizes these virus types:

Table 1

Summary of aphid transmitted potato viruses.

	Persistent	Non-persistent
Potato virus	*leafroll virus*	*virus Y and virus A*
Acquisition time	*several hours*	*a few seconds*
Latent period	*hours-days*	*none*
Inoculation time	*several hours*	*a few seconds*
Retention time	*lifetime of aphid*	*a few minutes–several hours*
Vector type	*colonizing*	*non-colonizing and colonizing*

It is important to note that PLRV is spread by aphids that colonize (reproduce in) potato (predominantly *Myzus persicae* (Sulzer), the green peach aphid). Aphid species that do not colonize potato would not normally feed long enough to acquire or inoculate the virus. Additionally, luteoviruses, of which PLRV is an example, have specific relationships with their aphid vectors. The viruses must be specifically recognized by receptors on cell membranes of the accessory salivary glands to be transmitted (Gildow, 1987). This may explain the fact that although *Macrosiphum euphorbiae* (Thomas), the potato aphid, can be found colonizing Idaho potato crops, it is not an important vector of PLRV (Kennedy, Day and Eastop, 1962; Hille Ris Lambers, 1972).

In contrast to the situation with potato leafroll virus, PVY, and PVA, which are closely related viruses, are spread primarily by non-colonizing aphids (Rydén et al., 1983). Non-persistent viruses are presumed to be spread through contamination of the mouthparts (Harris, 1977) and can be acquired and inoculated in as little as 5 seconds. Transmission efficiency actually declines after about a minute of feeding (Bradley and Rideout, 1953). We estimate that Idaho has at least 500 species of aphids. With few exceptions, aphids are highly selective with regard to their host plants, and only two of the aphid species found in Idaho, green peach aphid and potato aphid, will regularly colonize potato; however, many species of winged aphids land on potato crops because of their green color. They usually probe briefly, presumably to taste the plants to determine their acceptability as host plants. If potato is not a suitable host, the aphids move on, possibly to another potato plant. Unfortunately the brief probes are sufficient to acquire and transmit PVY and PVA. Both common colonizing aphid species can also transmit PVY and PVA.

Epidemiology and control of PLRV

Eliminate sources of primary infection.

As with any plant pathogen, the first priority for control is to eliminate sources of virus. This starts with the use of virus free seed. Secondly, isolation from PLRV reservoirs should be considered. Potential reservoirs include infected potato crops, volunteer potatoes, and garden potatoes. An aphid that has acquired PLRV remains infective for its lifetime, which is the reason for the term "persistent." Thus, a safe isolation distance would be the potential flight range of a green peach aphid. This is not known, but we do know that some species of cereal aphids fly at least 20 miles (Halbert et al., 1990) and we can assume that green peach aphids can also fly at least this distance (20 miles).

Control green peach aphids.

The green peach aphid is predominantly holocyclic in Idaho, meaning that it has a sexual cycle in the fall and overwinters as eggs on peach and (to a much lesser extent) apricot trees (Bishop, 1967). In eastern Idaho seed production areas, these trees are scarce due to our cold winters and fluctuating spring temperatures that make fruit set unlikely in most years. Because of the scarcity of winter hosts, we have the opportunity to minimize green peach aphid populations in seed areas. The most likely source of green peach aphids in Idaho seed production areas is infested bedding plants, particularly peppers and eggplants (Bishop and Guthrie, 1964; Halbert and Mowry, 1992). These plants frequently will have small colonies of green peach aphids in the newest leaves at the tops of the plants (Fig. 4). Inspection of incoming bedding plant shipments from western Idaho or surrounding states, or alternatively, inspection of nurseries and outlets in eastern Idaho, would help reduce green peach aphid populations in the seed areas (Bishop, 1967).

Figure 4
Green peach aphid, Myzus persicae (Sulzer), colonization on an eggplant transplant. Note that aphids are in the newest leaves.

Finally, it is possible to control secondary spread of PLRV by killing green peach aphids with insecticide. Both systemic and foliar applied insecticides can be useful. Systemic insecticides are particularly useful for PLRV control since the green peach aphid must feed for a period before transmission occurs. Sprays should be based on populations of green peach aphids in the crop. The threshold for commercial potato fields in eastern Idaho is 10 green peach aphids per 50 leaves for 2 consecutive weeks prior to August 15 (Byrne and Bishop, 1979). In western Idaho the threshold is 40 aphids per 50 leaves, using the same time constraints. The threshold is, of course, much lower for seed fields. No green peach aphid colonization should be tolerated in seed fields.

Epidemiology and control of PVY and PVA

Eliminate sources of primary infection.

Elimination of primary sources of PVY and PVA is similar to elimination of primary sources of

PLRV. Infected crops, volunteer potatoes, and garden potatoes are all possible sources. A major source of PVY and PVA is infected seed.

An experiment to determine the effect of seed-borne PVY on yield was performed by University of Idaho scientists at the Parma Research and Extension Center in Parma, ID. Seed lots of Russet Burbank, Russet Norkotah, and Shepody with different percentages of seed-borne PVY were created by blending PVY-infected and healthy seed in various proportions. The blended seedlots were grown in replicated field plots to obtain yield data. The results of this experiment demonstrate that increasing the percent PVY in a seed lot reduces the total yield in all three of the tested varieties. However, Shepody and Russet Norkotah appear to be more tolerant to seed-borne PVY infection than Russet Burbank.

What about aphid control?

Most aphid species in Idaho are inconsequential in economic terms, and a few that feed exclusively on weeds may even be beneficial. However, all aphid species are potential vectors of PVY and PVA.

Vector potential of a given aphid species depends on its ability to transmit the virus and its abundance. For example, green peach aphids are excellent vectors of PVY and PVA, but they are usually scarce in Idaho seed production areas and thus unlikely to be major vectors. On the other hand, some of the cereal aphids, while they may transmit PVY and PVA at lower rates than green peach aphids, are very abundant and thus likely to contribute more to spread of these viruses.

Vector potential of several species of cereal aphids was investigated in Idaho for bean common mosaic virus (BCMV), a virus that is classed in the potato virus Y group (Halbert et al. 1994). Each species was assayed for its ability to transmit BCMV. Suction trap collections were used to develop an index of vector potential. The potential vector index (PVI) was calculated for each species by multiplying average suction trap collection in bean production areas prior to August 1 for each year by percent transmission obtained in laboratory experiments. The cereal aphid index is the sum of the PVIs for Russian wheat aphid [*Diuraphis noxia* (Mordvilko)], rose grass aphid [*Metopolophium dirhodum* (Walker)], bird cherry oat aphid [*Rhopalosiphum padi* (L.)], greenbug [*Schizaphis graminum* (Rondani)] and English grain aphid [*Sitobion avenae* (Fabricius)].

Although green peach aphids are efficient vectors of BCMV, they contribute little to overall transmission of BCMV in Idaho in comparison to most cereal infesting species (Table 2). The Russian wheat aphid, though most abundant, did not contribute to the index because it does not transmit BCMV at all.

Recent similar experiments with PVY in Idaho have confirmed transmission by bird cherry oat

Table 2

Comparison of cereal aphid and *Myzus persicae* potential vector indices (PVI) for transmission of bean common mosaic virus 1985-1992.

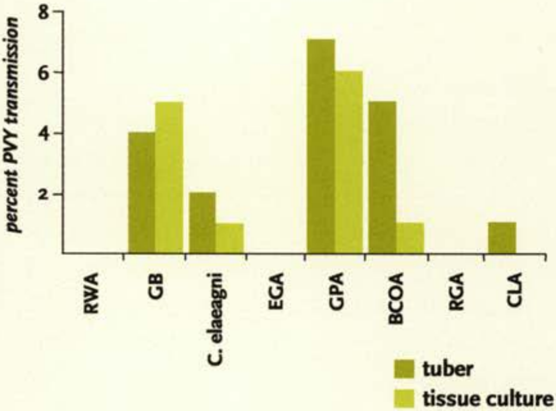
	1985	1986	1987	1988	1989	1990	1991	1992
Cereal aphid index	165	168	99	61	86	10	39	22
M. persicae index	4	3	1	4	1	2	4	1

aphid, greenbug, corn leaf aphid, and *Capitophorus elaeagni* (del Guercio), an abundant species that infests Russian olive and Canada thistle. These, along with Russian wheat aphid, are among the most common aphids collected in Idaho aphid surveys.

Green peach aphids were the most efficient vectors of PVY in transmission experiments, as expected (Fig. 5). Rose grass aphid and English grain aphid did not transmit the virus in our experiments. These latter two species are recognized vectors in Europe but were not able to transmit Idaho isolates of PVY even in mass inoculations using at least 100 aphids per test plant. Russian wheat aphid may transmit PVY at a very low rate (about 1/1000) and does not appear to be an important vector.

We did not do these transmission experiments with PVA, but previous studies have shown that PVA can be transmitted by the same aphid species that transmit PVY, although transmission efficiency is reported to be less (deBox, 1972).

Figure 5
Percent transmission of PVY by six species of cereal aphids, *C. elaeagni* and green peach aphid (GPA) using tuber grown and tissue culture grown Lemhi potato plants as indicators.
[Abbreviations: RWA–Russian wheat aphid, GB–greenbug, EGA–English grain aphid, BCOA–bird cherry oat aphid, RGA–rose grass aphid, CLA–corn leaf aphid.]



It is impossible to control PVY and PVA with insecticides because they can be transmitted by non-colonizing aphids in a matter of a few seconds. No known insecticide will work that fast! Virus free seed and isolation are the only practical options. Three miles should be sufficient for complete isolation of seed fields (Lee, 1992), because aphids will remain infective with PVY and PVA for only a few hours at most. Isolation of about 1/4 mile from sources of primary infection in our experience will eliminate most PVY spread.

Cultural practices such as reflective mulches (George and Kring, 1971), white paint on the plants (Marco, 1993) and closely spaced, dense crop canopies (A'Brook, 1964) can reduce aphid landings. Oil sprays have been shown to reduce transmission (Vanderveken, 1977). Tall barrier crops or trap crops can redistribute virus but not eliminate it. The distribution of virus in the field depends on deposition of wind-borne aphids behind the barrier and varies with the height and porosity of the barrier (Lewis, 1967, Lewis and Dibley, 1970). Some research has been done to develop aphid repellent chemicals, but there are no immediate prospects for an effective repellent for commercial use.

In the final analysis, control of PVY and PVA probably will depend on development of resistant varieties and strict seed certification procedures that include limited generation seed production schemes, early detection of infection and rapid flush out of infected seed lots. Prospects for successful chemical control are poor in the near future.

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