Management of Potato Virus Y (PVY) in Wisconsin Seed Potato Production

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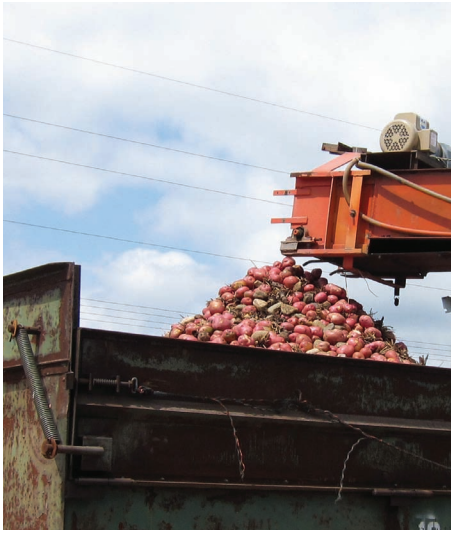
Potato Virus Y (PVY) is an aphid-transmitted virus that causes disease in numerous solanaceous crops including tomato, pepper, tobacco, and potato. PVY is a member of the *Potyviridae* family of viruses and is found worldwide. In potato, PVY is a yield-limiting pathogen that can cause as much as 50 to 80 percent yield loss in heavily infected commercial lots (Hane and Hamm 1999). The virus may also cause post-harvest losses due to tuber necrosis and reduced storage quality. PVY has been present in Wisconsin for decades, but in recent years it has re-emerged as a potentially serious disease problem. It affects potato production across the northern United States and in eastern Canada. A plausible explanation for this recent threat is that it results partly from new genetic recombinant strains of the virus that can cause tuber necrosis, partly from the establishment of a new aphid vector (*Aphis glycines*, or soybean aphid) in the Midwest and eastern United States, and partly from the widespread adoption of potato varieties which show only very mild symptoms of PVY infection.

Potato producers at risk

Both commercial and seed potato growers are at risk of direct yield loss due to PVY infection when levels exceed established tolerances. Commercial growers of fresh-market, processing, and chip potatoes are at risk of reduced yield and tuber storage quality if PVY-infected seed pieces are planted. Seed growers are at risk of having their lots downgraded or even rejected from certification due to PVY infection. (Allowable tolerances for PVY infection in Wisconsin seed lots are 0.5 percent infected seed pieces for 'Foundation' class and 5.0 percent for 'Certified' class.)

The risk of seed lot downgrading and rejection has increased in recent years. This increased risk is due to several factors that make visual assessment and roguing (removal) of infected plants challenging. In the past, potato seed certification procedures were extremely successful at managing PVY by relying on visual assessment of disease symptoms. Roguing of diseased plants maintained PVY infection levels below allowable tolerance standards established by state agencies. Recently, however, several major changes have contributed to the re-emergence of PVY. First, there has been a shift from virus strains that cause noticeable rugose mosaic symptoms to strains that cause mild or transient symptoms. Second, cultivars that show mild or no PVY symptoms have been released and widely accepted. Third, increased aphid activity and virus transmission late



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in the season often result in disease that causes no foliage symptoms. Taken together, these factors have contributed to recent challenges in visual identification of infected plants. As a result, infected plants can be overlooked in the roguing process, causing virus levels to build in each successive seed crop.

The number of clean seed potato lots in Wisconsin—lots not downgraded or rejected for certification—varied significantly from year to year during the 23 years from 1987 to 2010 (see figure 1). A major cause for the historical downgrades and rejections has been infections of PVY, most often in asymptomatic varieties. In recent years, seed potato producers working with the Wisconsin Seed Potato Certification Program have made significant progress in reducing levels of PVY in commercial seed stocks.

PVY infection and transmission in the upper Midwest

PVY is spread from plant to plant by mechanical means or by aphids. Mechanical transmission generally occurs when an infected plant and an adjacent healthy plant are wounded by wind or human activity (such as operating farm equipment in a field). The wounds of an infected plant leak sap that contains the virus, and the wound of a nearby healthy plant may take in some of that virus when the two plants touch. Mechanical seed cutting can also spread PVY, which is why it is always best to sanitize seed cutting equipment before using it for another variety or seed lot.

The more efficient and rapid form of transmission in fields involves aphid vectors. In general, aphids spread PVY over short distances (several hundred yards) on their piercing-sucking mouthparts. When an aphid feeds on a PVY-infected plant, virus particles adhere to the tips of its mouthparts. If the aphid then moves to a healthy plant and begins to feed, the virus particles are released and transferred to the healthy plant, leading to PVY infection.

Figure 1. Percent of clean seed lots reported in the Wisconsin post-harvest, winter grow-out test through a 23-year interval, 1987 to 2010. For all cultivars, PVY infection is nearly always the reason seed lots are rejected for certification. Resistant varieties are rarely rejected.

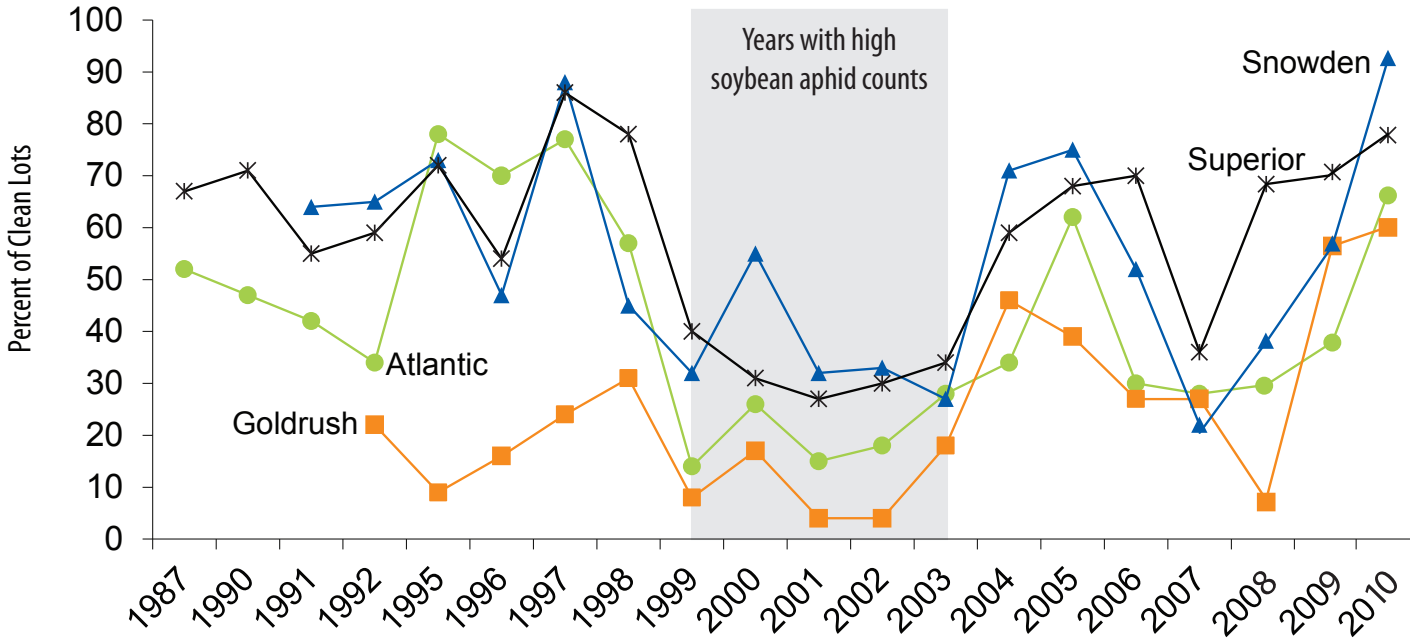


Figure 2. Soybean aphids (*Aphis glycines*) on a soybean leaf prior to midsummer flights.

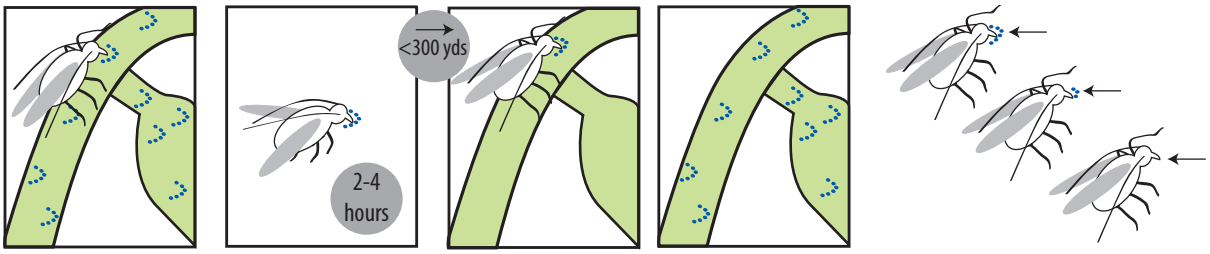
After an aphid has acquired the virus, it generally transmits it to uninfected plants for only a short period of time, usually less than two to four hours. How long the virus persists on the aphid mouthparts depends on the amount of time the aphid feeds and the number of plants the aphid visits. Frequent feeding attempts can quickly clean the mouthparts of virus and subsequent transmissions are less likely.

PVY may be transferred to and from potato plants by more than 50 species of aphid. These include species for which the potato plant is not a preferred host (DiFonzo 1996). The reason for this is that aphids searching for a preferred host will sample the sap of various plants and in so doing may transfer PVY to potatoes. Infected seed tubers are the principal source of PVY that aphids spread to other potato plants in the Midwest and eastern United States—which underscores the importance of starting with clean seed.

Historically, the aphid PVY vectors of concern have been the green peach aphid (*Myzus persicae*), bird cherry-oat aphid (*Rhopalosiphum padi*), potato aphid (*Macrosiphum euphorbiae*), and pea aphid (*Acyrthosiphon pisum*) (Difonzo et al. 1997). Soybean aphid (*Aphis glycines*), a species introduced into Wisconsin in 2000, is a new and noteworthy PVY vector in the North Central states (Alleman et al. 2002). Although individual soybean aphids are inefficient vectors of PVY, large populations of the winged stages (alatae) frequently develop and disperse in massive mid to late summer flights during which the soybean aphid contributes significantly to the spread of PVY in Wisconsin's potato crop (see figure 2).

Soybean aphid colonization and development during summer months occur primarily on soybean. Toward the end of the potato growing season, primarily late July through mid August, large numbers of soybean aphids take flight, leaving their summer hosts and dispersing into other crop fields, including potato fields. The timing of their flight leads to mid and late summer spread of PVY that often results in asymptomatic infections—infections that cause no foliar symptoms but sometimes cause tuber infections. These asymptomatic infections increase the likelihood that PVY will go unnoticed in the field.

Aphid Transmission of PVY



Non-PVY infected aphid feeds on plants infected with PVY. As the aphid feeds, PVY particles adhere to mouthparts.

The aphid moves to new plants, remaining infective for 2-4 hours, depending on how many plants it feeds on and for how long.

The infected aphid releases the virus into a new plant as it feeds.

The virus replicates within the new plant. Over time, this plant serves as a source of virus.

As the aphid continues to feed on uninfected plants, PVY is "cleaned" from its mouthparts.

▲ **Figure 3.** A Yukon Gold tuber (top) when infected with certain strains of PVY is prone to develop potato tuber necrotic ringspot disease (bottom).

Symptoms of PVY

Once infected, a potato plant can express symptoms in as few as 10 days, depending on the variety. Symptoms of PVY infection are variable and range from mild (foliar mottling, streaking, and mosaic) to severe (leaf necrosis, leaf drop, and stunting). The severity of the symptoms depends on the potato cultivar, environmental conditions, and the strain of PVY infecting the plant.

Some varieties for instance, Dark Red Norland and Yukon Gold, are highly susceptible to damage from PVY infection. A rugose mosaic symptom is characteristic in several susceptible varieties and is most commonly associated with infections of PVY^{O}. Infections in other varieties cause responses ranging from a mild mosaic to a hypersensitive (severe necrotic) reaction. In some varieties, necrosis may progress to total leaf collapse, with dead leaflets clinging to the stem. Some varieties with a strong hypersensitivity reaction often display field resistance, a condition in which the above-ground plant can be infected but the daughter tubers often remain healthy. When infected with certain strains of PVY, tubers of Alturas, Highland Russet, and Yukon Gold are prone to develop the sunken necrotic lesions of potato tuber necrotic ringspot disease (see figure 3).

Environmental factors influence PVY symptom severity, so signs of disease may vary by year and location. Additionally, the health of the plant before infection and the age of the plant when infected can affect symptom development and disease progression. Ordinarily, a plant that is more physiologically mature when infected expresses fewer and less severe disease symptoms. Some of the newer (and often asymptomatic) varieties possess markedly less of this mature plant resistance, and thus they are subject to higher levels of tuber infection.

The particular strain of PVY that infects a potato plant also influences symptom severity. Historically, the PVY^{O} strain, a strain which produces predictable and visible symptoms, has been almost the only PVY strain in Wisconsin. In recent years, however, up to a third of PVY strains found in Wisconsin have been $PVY^{N\text{-}Wi}$, a strain that causes inconsistent symptoms that are difficult to diagnose (see tables 1 and 2).

▼ **Table 1.** PVY strains commonly detected in the United States and associated symptoms.

PVY Strain	Common symptoms
PVY^{O}	Mild to severe leaf mosaic, rugosity, crinkling, severe systemic necrosis, leaf drop, yellowing of leaflets, and dwarfing. Symptom expression depends on the cultivar.
PVY^{C}	An uncommon strain causing stipple streak in select cultivars, rugosity, crinkling, severe systemic necrosis, leaf drop, and dwarfing.
PVY^{N}	Mild leaf mottling and necrosis, frequently undetected; some isolates cause potato tuber necrosis ringspot disease; often yield and quality losses occur. PVY^{N} strains are so-named because they cause necrosis in tobacco.
$PVY^{N\text{-}Wi}$	A strain that has parental components of PVY^{N} and PVY^{O}. Symptoms are often similar to those caused by the PVY^{N} parent, including mild mottling.
PVY^{NTN}	A recombinant strain differing from $PVY^{N\text{-}Wi}$ strain in that it causes severe mosaic and potato tuber necrosis ringspot disease.

Table 2. PVY strains identified in the 3-year survey of the U.S. seed potato crop (Baldauf et al. 2006).

Totals	Number of Samples Analyzed	PVY^{O}	$PVY^{N\text{-}Wi}$	PVY^{NTN}	strain mix
2004	865	511	210	36	11
2005	749	467	177	39	13
2006	722	438	119	35	66
3 years	2336	1416	506	110	90

An example of how different PVY strains cause different levels of symptom severity. On the Pike variety, $PVY^{N\text{-}WI}$ symptoms (top) are mild. PVY^{O} symptoms are more severe (bottom).

Using seed certified to be free of PVY is one strategy to exclude the virus from the farm.

Managing PVY

For many years seed potato certification programs succeeded in maintaining PVY levels at low and acceptable levels. More recently, however, the emergence of new strains that cause symptoms which are difficult to visually detect, the widespread planting of symptomless varieties, and an increase in the number of late-season aphid vectors require the deployment of more integrated tactics for successful management of PVY. Recommended management practices focus on preventing the disease by excluding sources of the virus from the planted crop, reducing the attractiveness of the growing crop to migrating aphids, and reducing the likelihood that infectious aphids will feed on the crop.

Try to exclude PVY from the farm. Buy seed certified to be free of PVY (and other pathogens) and classified as either foundation or certified. It is best to rely on post-harvest test data to determine the incidence of PVY in seed potatoes, because summer inspection data may not provide the best estimate of incidence in harvested tubers.

Be selective in choosing varieties to plant. When possible, plant resistant varieties. There are several moderately resistant cultivars currently available for production. Varieties with moderate resistance include Villetta Rose, Eva, Rio Grande Russet, and Premier Russet. Types of resistance vary among cultivars, and mechanisms of resistance are not well understood. In general, potato plants fall into three categories:

Susceptible plants. These can be infected, and the virus will multiply and move through the plant. Symptoms may or may not appear.

Resistant plants. These may become infected, but viruses replicate slowly, and there is limited systemic movement of virus.

Immune plants. These plants can be locally infected, but the virus will not replicate in the plant.

An example of an asymptomatic variety. PVY symptoms are only evident on Silverton Russet for a few weeks in the summer.

Avoid planting asymptomatic varieties. Asymptomatic varieties are susceptible potato varieties that allow PVY to replicate and move throughout the plant but show only mild disease symptoms. These "symptomless carriers" often go undetected in the field and serve as sources of virus inoculum from which aphids can acquire PVY that they then transmit to healthy plants. Several cultivars, including Shepody, Silverton Russet, and Russet Norkotah, are symptomless carriers of PVY and should be avoided when possible.

Reduce bare soil around potatoes. The color contrast between plant material and bare soil has been shown to attract aphids, causing more aphids to alight in the potato canopy. Reducing the amount of bare soil around and between potato plants can reduce aphid settling rates in the field and thus may reduce the amount of PVY inoculum the crop is exposed to. Here are some strategies to reduce color contrasts in a field:

- Don't separate cultivars with bare ground or drive alleys.
- Reduce planter skips.
- Rogue only when fewer than three plants in a row need to be removed. Removing three or more adjacent plants has been reported to increase PVY incidence in a field (Davis et al. 2009).
- Plant into reflective surfaces. Polyester or polypropylene sheets, and mulches of aluminum foil, white plastic or oat straw, reflect light in a way that deters aphids from landing. The reflected light prevents the aphids from recognizing the color contrast between soil and plants.

Rye is a common barrier crop. Barrier crops can help reduce PVY by effectively "cleaning" the mouthparts of migrating aphids before they enter the potato field.

Plant a barrier crop. A barrier crop is a crop that is a not a host for PVY and that is planted to create a border several yards wide around a potato field (no gap should exist between the barrier crop and the potato crop). Because of the color contrast between plant material and bare soil at the outer edge of the field, migrating aphids will be more likely to land in the barrier crop than in the potatoes. When aphids carrying PVY probe the barrier crop to see if it is a suitable host, the PVY will be effectively "cleaned" from their mouthparts. If aphids then move from the barrier crop into the potato field, they will be less likely to be carrying PVY from outside the field. Common barrier crops include rye, sorghum, and wheat.

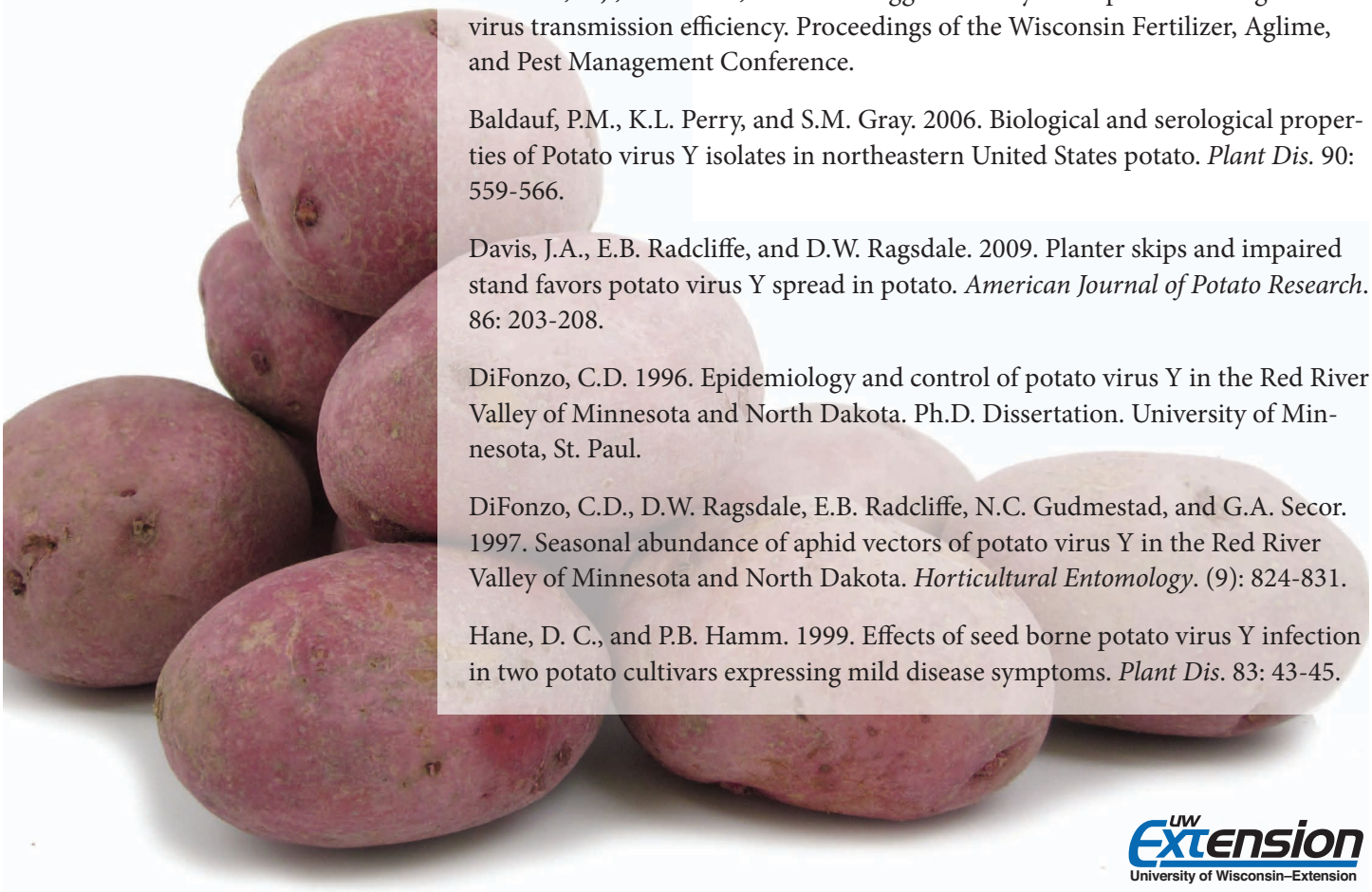
Plant early and top-kill early. The soybean aphid is a major vector of PVY late in the growing season. Killing potato vines prior to the major soybean aphid flights may prevent late-season virus infections, a strategy known as avoidance in time. For this strategy to be effective, the vines in the field must be completely killed. Otherwise plants will produce new growth that will attract aphids. Although early top-kill reduces tuber bulking, farmers who plant early will be able to have a harvestable crop and prevent the transfer of virus both between fields and within fields. Regional suction trapping and local field trapping can help detect when an influx of soybean aphids occurs.

Avoidance in time strategy. Top-killing potato vines can prevent late-season PVY infection.

Use behavior-modifying foliar sprays. Application of insecticide will seldom achieve any practical or permanent control of PVY. The systemic neonicotinoid insecticides have proven invaluable in controlling many of the potato colonizing aphid species (e.g., green peach and potato aphid), but because many of the aphids responsible for PVY spread are transient (noncolonizing) species, insecticides do not play a large part in the recommended PVY management program. Some foliar sprays, however, deter aphids from feeding. New products labeled as selective feeding blockers rapidly paralyze aphids that attempt to feed. Also, the application of a highly pure, light, and refined mineral oil to the surfaces of plant leaves will reduce virus transmission by disrupting the ability of the virus to attach to aphid mouthparts. At-plant systemic insecticides are part of the overall pest management program for most seed potato producers, and these compounds very likely do limit some secondary (plant-to-plant) spread of PVY by controlling colonizing aphid species such as green peach aphid or potato aphid (see table 3).

Table 3. Registered insecticide options to limit spread of PVY, grouped by Mode of Action (MoA) class. (Insecticide Resistance Action Committee, http://www.irac-online.org)

Mode of Action Class	Group	Active Ingredient	Trade Names	Application Technology (consult labels for appropriate rates with associated use patterns)
Nicotinic acetylcholine receptor (nAChR) agonists	4A	imidacloprid	Admire® Pro, Gaucho®, Provado®	In-furrow Seed treatment Foliar
		thiamethoxam	Platinum®, Cruiser®, Actara®	In-furrow Seed treatment Foliar
		clothianadin	Belay®	In-furrow Seed treatment Foliar
		dinotefuran	Scorpion™	In-furrow Foliar
		acetamiprid	Assail®	Foliar
Selective homopteran feeding blockers	9B	pymetrozine	Fulfill®	Foliar
	9C	flonicamid	Beleaf ™	Foliar
Inhibitors of acetyl CoA carboxylase	23	spirotetramat	Movento®	Foliar
Narrow-range mineral oil	NA	petroleum oil	Aphoil®, Stylet Oil®	Foliar



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