A Pacific Northwest Extension Publication

Oregon State University • University of Idaho • Washington State University

PNW 633 • May 2017

Potato Psyllid Vector of Zebra Chip Disease in the Pacific Northwest

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Zebra chip (ZC) is a destructive disease of potatoes in North America and other parts of the world. It has been very costly to manage in potato crops and has caused millions of dollars in losses to the potato industry in the southwestern United States, particularly Texas. ZC is transmitted by the potato psyllid, which is the only known vector in potato (Figure 1). The disease was first recorded in Idaho and the Columbia Basin of Washington and Oregon late in the 2011 growing season. This region produces more than 56 percent of the potatoes grown in the United States, so the presence of ZC has the potential to be economically devastating.

Since 2012, the incidence of ZC has been relatively low even though the abundance of the vector has fluctuated (Figure 2, page 2). However, because it could have strong negative effects on the North American potato industry, a comprehensive plan is needed to tackle the vector and the pathogen.

Despite the progress made to better understand the ZC vector and pathogen, further information is needed to fully manage this complex insect-pathogen system. This publication provides basic up-to-date information regarding this pest complex.

Photo: Rondon's Irrigated Agricultural Entomology Lab (IAEP) (by A.F.M.), © Oregon State University

Photo: E. Wenninger, University of Idaho

Figure 1. Potato psyllid adult

Brief history and distribution of ZC

ZC was first documented in potato fields near Saltillo, Mexico in 1994. In the early 2000s, the disease was reported in southern Texas, and by 2006, ZC had spread to all potato production areas in Texas. Since then, ZC has been found in Arizona, California, Colorado, Kansas, Nebraska, Nevada, New Mexico, Wyoming, Oregon, Washington, Idaho, and Utah. ZC is also found in Guatemala, Honduras, Mexico, New Zealand, Nicaragua, and Australia (Figure 3, page 3).

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The bacterium

The pathogen associated with ZC is the bacterium '*Candidatus* Liberibacter solanacearum' (a.k.a. '*Ca*. L. psyllaurous' or Lso), vectored to potato by the potato psyllid, *Bactericera cockerelli* (Šulc) (Hemiptera: Triozidae) (Figure 1, page 1). Worldwide, 20 psyllid species from three families are associated with seven different "species" of Liberibacter.

Economically important members of the '*Ca*. Liberibacter' group are vectored by at least five psyllid species associated with important diseases of citrus, solanaceous crops, and carrot. '*Ca*. L. asiaticus', '*Ca*. L. africanus', and '*Ca*. L. americanus' are associated with citrus greening and are vectored by the Asian citrus psyllid *Diaphorina citri* Kumayama and the African citrus psyllid (*Trioza erytreae* Del Guercio). '*Ca*. L. solanacearum' severely affects carrot crops in Europe and is transmitted by the carrot psyllid *Trioza apicalis* Foerster in northern Europe and *Bactericera trigonica* Hodkinson in the Mediterranean region. This pathogen also has been reported in pepper in Mexico and tobacco in Guatemala.

Detection of '*Ca*. Liberibacter' is based on polymerase chain reaction (PCR) amplification. Based on Simple Sequence Repeat (SSR) marker analysis, it was determined that a high level of genetic diversity in Lso is present in the United States and Mexico but that none of the three distinct genetic types of the bacterium (designated Lso "A" and "B") are restricted to particular geographic regions. In potatoes, the bacterium affects the phloem tissue, causing foliar and tuber symptoms, including abnormal foliage, significant internal tuber necrosis, and higher than normal sugar concentrations in tubers.

Biology of the vector

The potato psyllid is a phloem-feeding insect that has an extensive host range across at least 20 different plant families but reproduces mainly on potatoes (*Solanum tuberosum* L.) and other members of the nightshade family (Solanaceae), including tomatoes (*S. lycopersicum* L.) and bittersweet nightshade (S. *dulcamara* L.). This insect can complete a generation in less than a month under optimal conditions (75°F to 80°F or 24°C to 27°C). Although plants from the family Convolvulaceae (bindweeds) are also able to support the normal development of the psyllid, they are not a preferred host for the vector and are not hosts for the ZC pathogen.

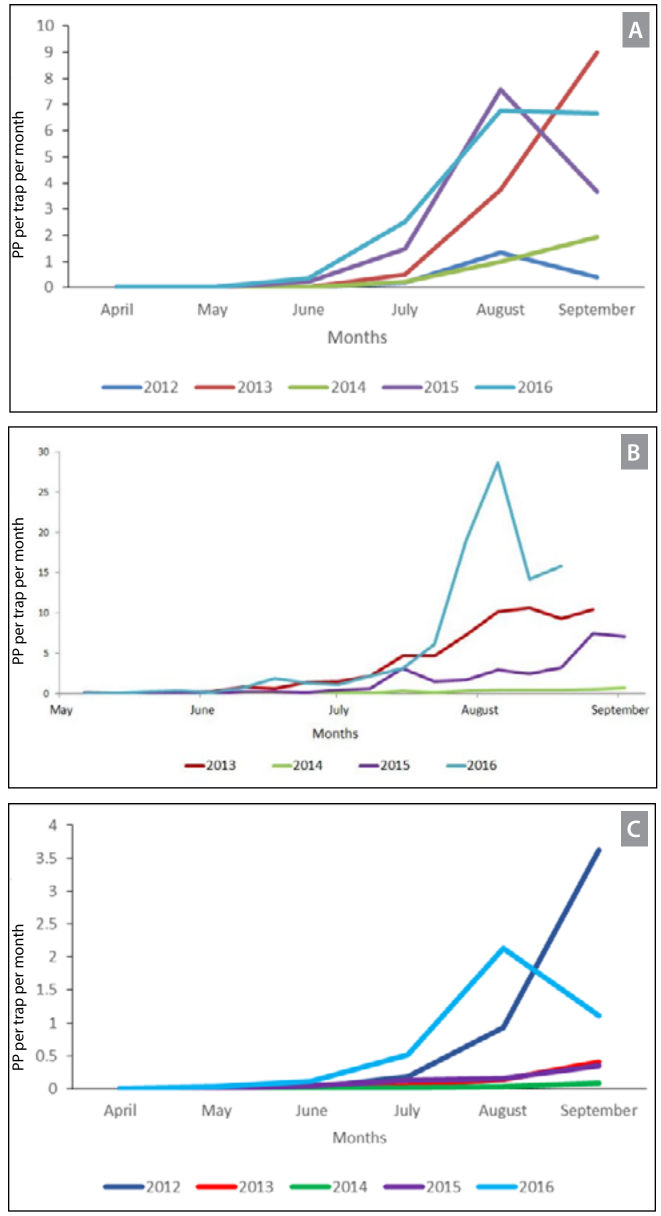

Figure 2. Population dynamics of the potato psyllid in Oregon (A), Washington (B) and Idaho (C)
[Sources: Oregon (S. Rondon), Washington (C. Wohleb), Idaho (E. Wenninger)]

To date, four haplotypes (distinct genetic types of the potato psyllid that are associated with different geographical regions) of the potato psyllid have been identified; they are the central, western, northwestern, and southwestern haplotypes. In Oregon and Washington, the northwestern and western haplotypes are predominant, while in Idaho, all haplotypes are present.

A related psyllid, *B. maculipennis*, occurs in high numbers on bindweed and is sometimes captured on traps in potato fields. This psyllid has black markings on the wings (which are not present on potato psyllid) and is not a threat to commercial crops (Figure 4, page 3).

Eggs

The football-shaped eggs (Figure 5, page 4) are extremely small, just slightly larger than potato leaf hairs. Eggs are yellow-orange and are attached individually to leaves on a short stalk. They are usually laid in the plant canopy on the underside and along the edges of leaves. A hand lens with at least 10× magnification is required to see them. Eggs hatch in 6 to 10 days, depending on temperature. Warmer temperatures (78°F to 82°F or 26°C to 28°C) favor early hatching, although temperatures above 90°F (32°C) negatively impact reproduction and survival.

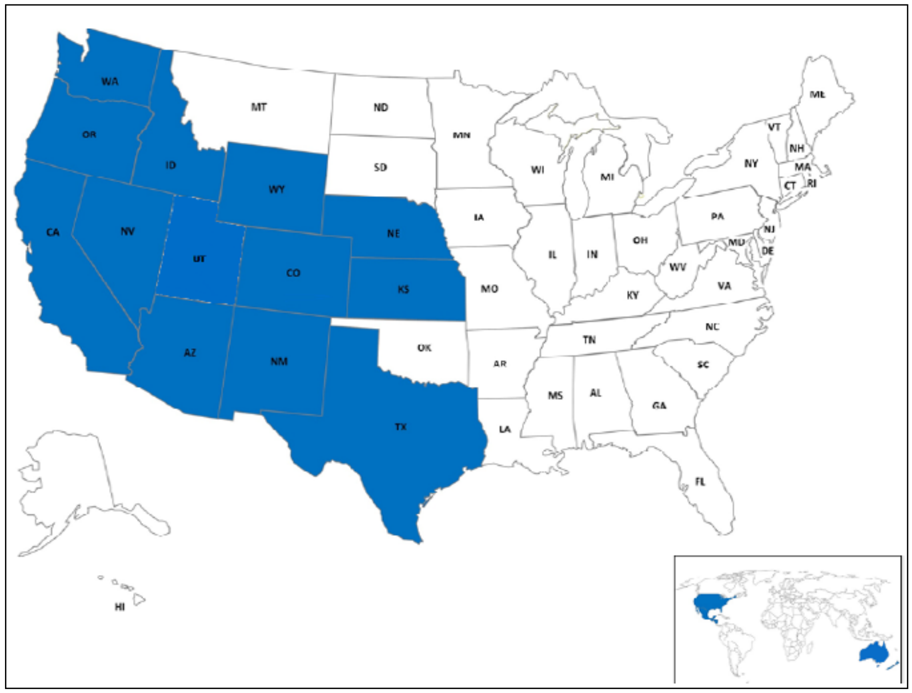

Figure 3. Zebra chip distribution map

Nymphs

Psyllid nymphs are flat and yellow to green with a fringe of short spines around the edge of the body. Larger nymphs have distinct "wingpads" on their dorsum. In warm temperatures (78°F to 82°F or 26°C to 28°C), immature psyllids go through five stages of development in as few as 13 days. Nymphs (Figure 6, page 4) look like immature, soft-scale insects or whiteflies. In contrast to whiteflies or scales, psyllid nymphs move readily when disturbed.


Photo: R. Cooper, USDA-ARS

Figure 4. The bindweed psyllid is occasionally captured in potato psyllid monitoring traps; it can be distinguished from potato psyllid by the black markings of the wings.

Adults

Psyllid adults are about 0.08 inch (2 mm) long and have clear wings that are held roof-like over the body when at rest. They are closely related to aphids and leafhoppers and resemble small cicadas, winged aphids, or bark lice.

The potato psyllid is predominantly black with white markings (Figure 1, page 1). The first abdominal segment shows a broad white band and the last segment has an inverted white "V." Newly molted adults are yellowish green (Figure 7, page 4), and are, therefore, difficult to distinguish from other insects. Adult psyllids jump readily when disturbed. An adult female can lay over 1,000 eggs during her lifetime and can pass the ZC pathogen directly to her offspring.

Overwintering

Potato psyllid has long been known to be present throughout the Pacific Northwest (PNW). It was thought that psyllids were unable to overwinter in the area and that reintroduction in any given season required migration on air currents from the southwest part of the United States, possibly California. However, observations made during the winter and spring confirm that adult psyllids can survive the winter in certain areas of the PNW (Figure 8, page 5).

Psyllid have been found on *S. dulcamara* L., commonly known as bittersweet nightshade, bitter nightshade, blue bindweed, or poison berry. This perennial weed, native to Eurasia, is found in wet and dry fencerows, pond margins, low woods, and

Photo: Rondon's Irrigated Agricultural Entomology Lab (IAEP) (by A.F.M.), © Oregon State University

Photo: E. Wenninger, University of Idaho

Figure 5. Potato psyllid eggs

Photo: E. Wenninger, University of Idaho

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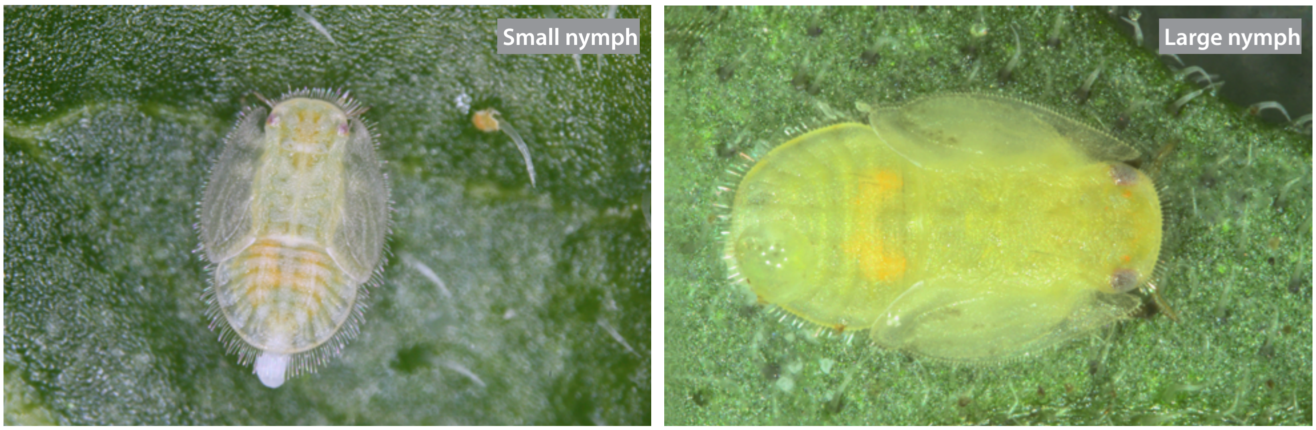

Figure 6. Potato psyllid nymphs

roadsides throughout the PNW. The psyllid also overwinters on the perennial shrub matrimony vine (*Lycium* spp., also called goji berry or wolfberry) (Figure 9, page 5). The shrub is well adapted to arid/semiarid climates and grows in dense patches that are often close to historic homesteads or cemeteries. Research confirms that not only can potato psyllids overwinter in the PNW but that a small percentage of the overwintering weeds can harbor the ZC bacterium.

Photo: Rondon's Irrigated Agricultural Entomology Lab (IAEP) (by A.F.M.), © Oregon State University

Figure 7. Newly molted potato psyllid

Direct feeding damage

Psyllid nymphs and adults feed similarly to aphids, probing host plants with their needle-like mouthparts and sucking plant juices (Figure 10, page 5). Because they feed directly on the plant, **potato psyllids can cause plant damage even when not carrying the bacterium responsible for ZC**. This phenomenon was observed in recent years when ZC bacterium was almost nonexistent in psyllids tested.

As they feed, psyllids inject toxins with their saliva that can cause leaf yellowing or purpling, smaller and fewer tubers, and misshapen tubers. This physiological condition is called "psyllid yellows" (Figure 11, page 6) and is generally less damaging than ZC, as it does not cause the characteristic ZC symptoms seen in the cut tuber or following frying.

Damage from the ZC pathogen

ZC usually requires about 3 weeks following pathogen inoculation by psyllids to produce symptoms in the foliage and tubers. Plants infected by ZC exhibit a range of aboveground symptoms that are similar to potato purple top and psyllid yellows, including stunting, chlorosis, leaf scorching, swollen internodes near apical portions, axillary bud and aerial tuber proliferation, necrosis of vascular system, and early death (Figure 12, page 6).

Symptoms in tubers include development of dark striped patterns of necrosis (Figure 13, page 7). The disease also alters the starch metabolism of infected tubers, converting starch into sugars in zones of the tuber.

The name "zebra chip" refers to the characteristic brown discoloration of the vascular ring and medullary ray tissues within the tubers that is amplified when tubers are sliced and fried into chips or French fries (Figure 14, page 7). Not all tubers from an infected plant will exhibit zebra chip symptoms. Though the defect is harmless to consumers, the flavor and color of the product is altered, making infected tubers unacceptable in both fresh and processing markets. Tissue of infected tubers will also oxidize rapidly, producing a pink-brown color after cutting or peeling. In addition to reducing tuber quality, ZC can cause significant yield reduction.

While there are differences in susceptibility across potato varieties, virtually all available commercial varieties will show symptoms of ZC in the foliage or tubers or both.

Abundance

In 2011–2012, when ZC was first reported in the PNW, psyllid adults were first detected in potatoes in early July. However, in recent years, adults have been detected in the upper Columbia Basin and Idaho in the last week of May and the first week of June. In the lower Columbia Basin, psyllids have been found the last week of May (Figure 2, page 2). In all geographical locations, potato psyllid adult numbers are relatively low during early to mid-season, but by late season, abundance can peak dramatically. It has been suggested that one reason for high numbers is the rapid movement of adult psyllids to nearby fields following the harvest of early planted potatoes.

Sampling

A sampling program to monitor psyllid populations is a fundamental tool for a successful integrated

Figure 8. Patch of *Solanum dulcamara* (bittersweet nightshade) in the PNW

Photo: D. Walenta, © Oregon State University

Figure 9. Potato psyllid overwintering site in the PNW: Lycium

Photo: R. Cooper, USDA-ARS

Figure 10. Potato psyllid feeding and damage

Photo: S. Rondon, © Oregon State University


Photos: S. Rondon, © Oregon State University

Figure 11. Psyllid yellow: yellow foliage, early sprouting


Photos: S. Rondon, © Oregon State University

Figure 12. ZC foliar symptoms

pest management program. Sampling programs are critical for decision-making strategies.

- **Yellow sticky cards.** Unbaited 3×5 inch (8×13 cm) yellow sticky cards are recommended to detect the first occurrence of psyllids in the area (Figure 15, page 7), though their sensitivity to confirm psyllids at low populations (i.e., early in the season) may be low. Attach cards to 28- to 30-inch (70- to 75-cm) wooden stakes and place them at canopy level; adjust the cards to plant canopy height by moving them along the stake.

  Start seasonal sampling as soon as the potato season begins. Replace sticky cards weekly. Sticky traps will likely be most useful for detecting psyllid migration into and out of fields. Spatial and temporal studies indicate that early in the season both psyllid abundance and ZC incidence are higher in field edges than in the interior of fields. As the season progresses, psyllids become more evenly distributed throughout the field. Placement of cards outside of fields, such as is recommended for beet leafhopper, is not effective for monitoring potato psyllids. Sticky cards have to be set 5 to 10 feet (152 to 305 cm) inside the field. The more cards that are placed in a field (minimum of 4 per field), the more likely you are to detect psyllids early.

- **Sweep net and aspirator or vacuum sampling device.** Considering that adult potato psyllids are active and fly or jump away when disturbed, a sweep net plus an aspirator or a vacuum sampling device such as a D-Vac or an inverted leaf blower can also be used to monitor psyllids (Figure 16, page 8). Texas A&M University recommends 100 sweeps from around the field perimeter.

  If you use a vacuum sampler, be sure to use it 5 to 10 feet (152.4 to 304.8 cm) inside the field edge for at least 5 minutes. It is more difficult to sort psyllids collected by these methods than to count them on a sticky card. For more information on using a sweep net, see the video "Sweep Net Technique" at https://www.youtube.com/watch?v=c5dVt3n1_EE.

- **Leaf sampling.** Collect 10 leaves from 10 locations among the 10 outer rows of the field (Figure 17, page 8). Collect full-size leaves from the middle of the plant to look for psyllid eggs or nymphs. You may need a hand lens to see these life stages. The nymphs usually reside on the underside of the leaf. Eggs are most commonly present on the leaf's edges and underside; however, if the psyllid population is high, eggs can be found on other parts of the leaves.

  Keep in mind that this is not the preferred method for determining the first occurrence of these insects. Leaf sampling confirms that psyllids are already colonizing the field, and ZC infection will likely have happened by then if the psyllids are carriers of the bacterium.

Action threshold

No action threshold exists for psyllids in potato. However, we suggest that **the threshold for action is first detection of potato psyllids at any level, in any life stage**. Psyllids can cause direct damage by feeding and as a vector of the ZC pathogen.

Non-chemical control

There are no effective non-chemical control tactics for potato psyllids, although research is underway in this area.

Chemical control

There are a number of insecticides registered on potatoes that have activity against potato psyllids in the adult stage, or immature stage, or both. Some insecticides with activity against adults and nymphs will also have activity against the eggs.

Season-long, weekly applications are used in areas where ZC has been problematic (e.g., in Texas, psyllids are present from planting to harvest). In the PNW, especially in areas that have had problems with ZC, the recommendation is to start chemical treatments as early as mid-May, since in the last several years adult psyllids were detected earlier (Figure 2, page 2).

Photo: S. Rondon, © Oregon State University

Figure 13. ZC fresh tuber damage

Photo: N. Olsen, University of Idaho

Figure 14. ZC fry damage

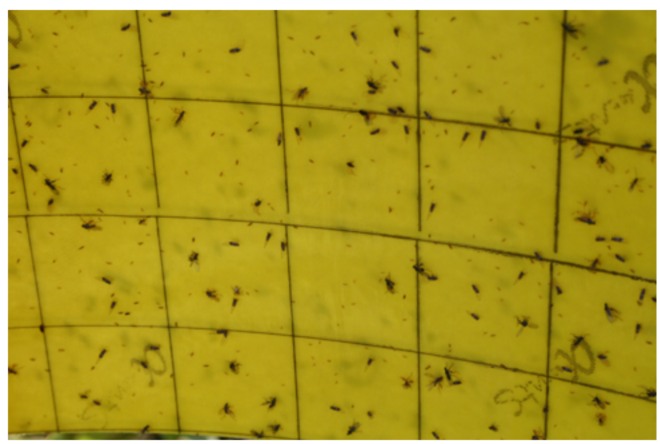

Photo: S. Rondon © Oregon State University

Figure 15. Yellow sticky card covered with potato psyllids

If you are in an area where psyllids are a constant problem, apply a systemic insecticide at planting or at hilling and then follow-up with a foliar insecticide program as the systemic insecticides near the end of their efficacy (Figure 18, page 8). Always read the product label carefully, follow state and federal laws, and consult your local Extension office or the Pacific Northwest Insect Management Handbook for specific insecticide recommendations. A list of chemicals can be found at https://pnwhandbooks.org/insect/vegetable/irish-potato/pesticide-tables-potato.

Planning ahead: Resistance management

The risk of insects developing resistance to insecticides can be reduced with adequate planning. In Mexico and Texas, imidacloprid and abamectin products are no longer effective against psyllids due to overuse. **In the PNW, there is no evidence of resistance to pesticides yet.**

To prolong the effectiveness of pesticides, pesticides of the same chemical family—that is, with same mode of action—should not be used more than two times per season. In addition, modes of action should be rotated between applications. Furthermore, if a neonicotinoid insecticide was used at planting, then a foliar neonicotinoid (or package mix that contains a neonicotinoid) should not be used later in the season. The widespread use of neonicotinoids in potatoes in the PNW increases the likelihood for resistance.

Pathogen development in storage

Research on the biology of the disease in storage is ongoing. Asymptomatic tubers produced by potato plants infected late in the season may develop ZC symptoms later in storage. Apparently, there is movement of the bacterium from the stolon end towards the bud end as the storage season progresses and, therefore, internal symptoms may continue to develop throughout the tuber with time. However, timing of infection appears to be critical to development of ZC during storage.

In research studies, 'Russet Burbank' plants infected a few days before vine kill developed few or no ZC symptoms, but plants infected a few weeks before vine kill were more likely to develop symptoms during storage. The timing of the development of the disease during storage as well as possible differences in responses among varieties remain to be studied. Movement of the bacterium from infected to healthy tubers in storage has not been documented. Experience with this disease in some locations suggests that infected tubers do not rot in storage. Tubers infected with the bacterium appear to exhibit altered turgidity or toughness of the tuber tissue and may be more susceptible to shatter bruising.

Photo: S. Rondon, © Oregon State University

Figure 16. Researcher using the inverted leaf blower

Photo: S. Rondon © Oregon State University

Figure 17. Leaf samples

Photo: S. Rondon © Oregon State University

Figure 18. Chemicals can be applied by at-plant, central-pivot, aerial, ground, or chemigation.

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Published June 2012. Revised May 2017.