X-disease phytoplasma (Western X)

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The X-disease phytoplasma (‘*Candidatus* Phytoplasma pruni’) is the primary cause of small, pale, tasteless and unmarketable cherries in Washington state. In peaches, plums, and nectarines, X-disease symptoms are typically yellowed, curled and shot-holed leaves, and small-deformed fruit. X-disease is present across North America, throughout Washington State, and at high incidence in Yakima, Benton, Franklin, Grant, and Chelan counties. It is also present in Douglas, Okanogan, Klickitack Counties, and Oregon in The Dalles area.

Figure 1. X-disease phytoplasma on Cristalina cherry.

Background

X-disease (Western X) is not a new disease, but Washington is experiencing new complications. It was first identified in cherry trees of Washington State in 1946. In a 1947 survey, about 1% of cherry trees were found to be infected, and it has remained present ever since, fluctuating in frequency. However, it has increased in prevalence dramatically in recent years, with pathogen strains, vectors, and environmental conditions that were not present in the previous outbreak.

Figure 2. X-disease phytoplasma on Bing cherry.

Symptoms

Infection reduces fruit size and quality in sweet cherries. In contrast to Little cherry virus 2 where fruit often has little flavor, fruit from X-disease infected trees are often bitter. Fruit have reduced fructose, glucose, and sorbitol content and in some cases total phenolic content increases (Wright et al. 2020). In addition to fruit symptoms you can see reduced growth/extension of infected limbs, sometimes leading to leaves crowding into dense clusters (rosette) when trees have been infected for multiple years.

Figure 3. X-disease phytoplasma on nectarine.

Symptoms in cherry

- Small and misshapen fruit.
- Poor color development.
- Fruit lacking in flavor/ bitter.
- Symptoms can be confused with unripe fruit until close to harvest.
- Symptoms are restricted to one/a few branches unless trees have been infected for multiple years.

Symptoms in peaches, plums, and nectarines

- Yellowed curled leaves.
- Leaf shot hole.
- Small-deformed fruit.
- Leaf yellowing symptoms on infected peaches and nectarines begin to appear about 2 months prior to

harvest, and get progressively worse, with shot holes appearing as the season progresses.

Symptom progression

1. Year 1: small fruit may be restricted to one branch or cluster, fruit color may develop normally, or individual pale to white fruit may be observed.
2. Years 2-3: systemically infected tree, small fruit observed on multiple or all limbs, and poor color development is pronounced.
3. 4+ years: cultivar dependent, but characterized by reduced fruit yield, and dieback of limbs.

Causal Organism

X-disease phytoplasma is not a virus, but instead is a type of wall-less bacterium known as a phytoplasma. The X-disease phytoplasma lives and replicates in the vascular phloem of infected trees, interfering with tree growth and development. Five major strains of ‘Ca. P. pruni’ have been found to cause X-disease in commerically grown *Prunus* species (Molnar et al. 2024). These strains differ in geographic distribution, severity, symptoms and vector transmissibility. Unfortunately, the dominant strains in the Pacific Northwest cause fruit symptoms, but not leaf symptoms or stunting, making them more difficult to scout for.

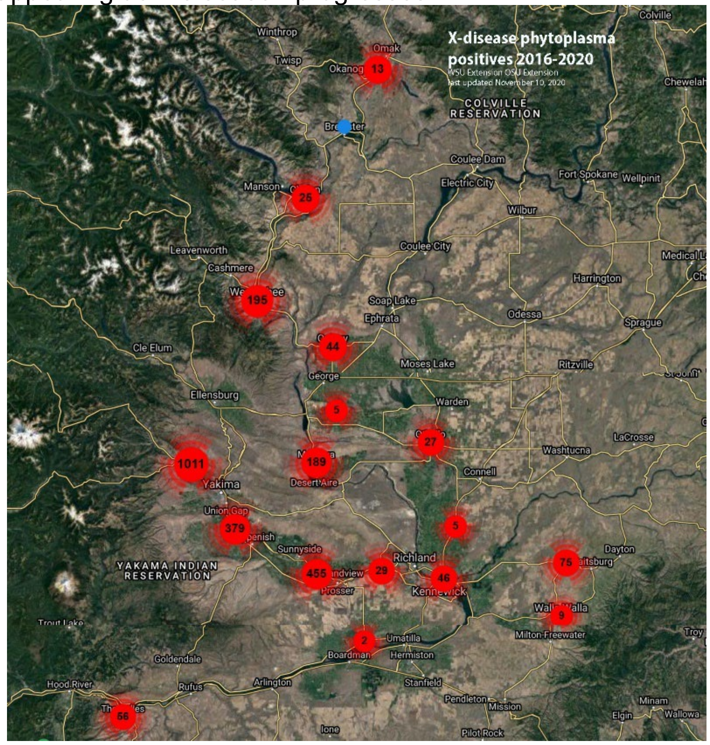


Figure 4. Distribution of documented positive samples for X-disease phytoplasma between 2016 and 2020.

Occurrence

X-disease is present across North America, throughout Washington State with high incidence in Grant, Yakima, Benton, Franklin, and Chelan counties, and present in Okanogan, Douglas, and Klickitat County and Oregon in The Dalles area (Molnar et al 2022).

Impacts

More than 238,856 trees equivalent to 974 acres of sweet cherries and 33,082 peach, nectarine, plum and apricot trees representing 81 acres were removed due to X-disease and Little Cherry Disease between 2015 and 2020 according to a recent survey conducted by WSU/ OSU Extension with 81 respondents who collectively manage 15,420 acres, 26% of Washington and Oregon total cherry acreage (Molnar et al 2022). Removed trees reduced revenue to the industry by an estimated $30 million in 2020 and $65 million between 2015 and 2020. Over the seven-year re-establishment period estimated lost revenue and establishment costs to growers is approximately $115 million.

Figure 5. *C. geminatus* (top) *E. variegatus* (bottom). Photo credit C. Reyes.

Host Range

X-disease phytoplasma infects most *Prunus* species, ex. cherries, peaches, nectarines, almonds, plums, and chokecherry. X-disease phytoplasma also infects a wide range of broadleaf plants. Previous work found dandelion, knotweed, goosefoot (lambsquarter), sagebrush, chickweed, mallow, alfalfa, puncture vine, tumble mustard, and flixweed were hosts (Jensen 1971). In a 2021 to 2023 survey 52 of 77 species tested were positive for X-disease phytoplasma. Plants from six families had significant numbers of positives including members of the *Asteraceae* (dandelion), *Malvacea* (mallow), *Amaranthaceae* (goosefoot/ lambsquarter & pigweed), *Polygonaceae* (knotweed), *Brassicaceae* (flixweed, tumblemustard, hoary bittercress, & shepherd's purse), and *Plantaginaceae* (plantain). All these species are common components of the orchard floor or are present around orchard borders. Twelve other plant families were less prevalent in orchards and had a small number of positives for X-disease phytoplasma including, *Apiaceae* (eg. queen anne's lace & wild carrot), *Caryophyllaceae* (chickweed), *Fabaceae* (clover), *Geraniaceae* (redstem filaree & wild geranium), *Lamiaceae* (henbit, purple dead nettle), Oxalidaceae (oxalis, ground sorrel), *Poaceae* (downy brome), Rosaceae (wild rose), *Solanaceae* (nightshades), and *Tribulus* (puncturevine).

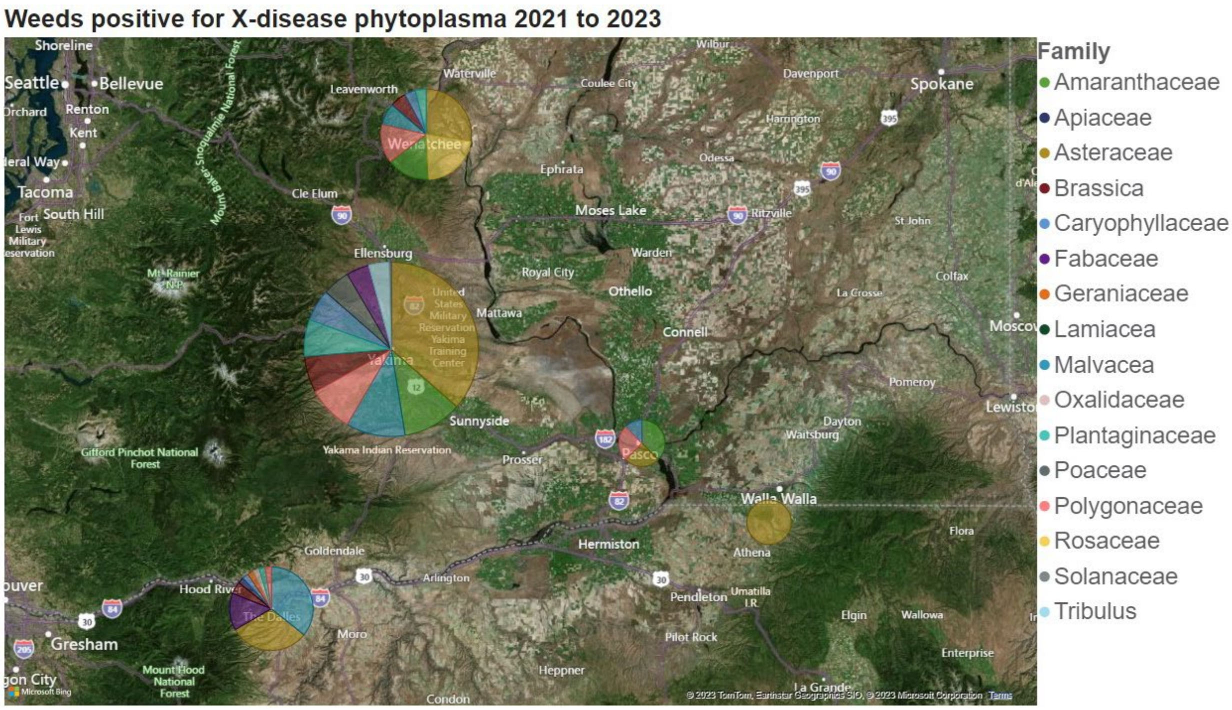
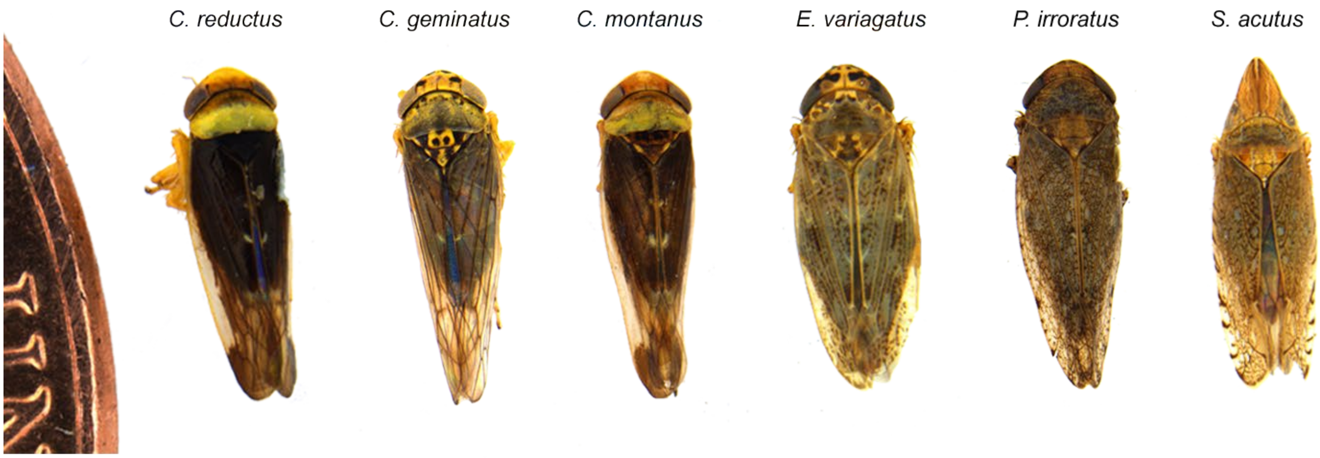


Figure 6. Map of alternative hosts for X-disease phytoplasma identified from orchards and orchard surroundings between 2021 and 2023. The larger the circle the greater number of positive samples.

Transmission

Grafting: X-disease phytoplasma is readily transmitted by all types of grafting.

Vector: Leafhoppers are the only known vectors. Seven leafhoppers are known to transmit X-disease phytoplasma: *Colladonus montanus reductus, Colladonus geminatus, Euscelidius variegatus, Colladonus montanus montanus*, *Fiebriella florii*, *Scaphytopius acutus*, and *Paraphlepsius irroratus* (Jensen 1969, Purcell and Elkinton 1980). In tests of over 2000 individuals no other leafhoppers were found positive for X-disease phytoplasma (Marshall et al., *in prep*). The only species found actively transmitting in that survey were *C. m. reductus*, and *C. gemintus*. *Colladonus montanus reductus* is the most common X-disease leafhopper vector in Washington followed by *E. variegatus* with low frequency of *C. geminatus* (Orpet et al, *in prep*). Low numbers of *S. acutus* were found in Washington surveys from 2020 to 2022 (Marshall et al., *in prep*, Northfield and Nottingham 2020). Research in the 1960s suggests *E. variegatus* appears to be a less effective vector than *C. reductus*, with a longer latency period (approximately 50 days compared to 30-35 days) (Jensen 1969). This finding aligns with our finding that field-collected *E. variegatus* never had enough phytoplasma in their mouthparts for transmission (Marshall et al., *in prep)*.



Leafhopper sizes are not relative or proportional. Actual specimens may vary in size.

Figure 7. *Leafhopper vectors of X-disease phytoplasma Colladonus montanus reductus, Colladonus geminatus,* Euscelidius variegatus, *Colladonus montanus montanus*, *Scaphytopius acutus*, and *Paraphlepsius irroratus. Not shown Fiebriella florii*. Photo credit C. Reyes.

Transmission by leafhoppers will vary depending on the level of infection in the block as well as numbers of leafhoppers. For example, in managed orchards with some X-disease incidence 10-15% may have acquired phytoplasma, while up to 2% of *Colladonus* spp. leafhoppers are able to transmit (Marshall *in prep*). However, in an unmanaged orchard with high levels of infection (50 of 50 trees tested positive) 40% of *C. m. reductus* leafhoppers had acquired the phytoplasmas.

Life Cycle of the Organism

The X-disease phytoplasma replicates in the phloem tissue of the tree. Over winter the phytoplasma numbers in the arial parts of the tree decrease (with small numbers remaining), and active, living phytoplasma cells overwinter in the roots. In the spring, the aerial portions of the tree become re-infected as the phytoplasma moves up the phloem of the tree, usually following the same general route as in the previous year. As a result, you may see symptoms in one limb for a year or more, but symptoms will eventually appear in additional limbs. Removing a symptomatic limb does not eliminate the phytoplasma since it is already in the root system before symptoms appear.

Vector Biology

In Washington *C. m. reductus* has three periods of peak adult abundance, June, August, and September/October (after harvest), indicating a potential for three generations (Marshall et al 2024). In California *C. m. reductus* was found to have a generation time of 56 days (Severin and Klostermeyer 1950). *C. m. reductus* fed on a wide range of hosts in feeding trials including mallow, alfalfa, cherry, peach, white clover, and dandelion (Northfield and Cooper 2020). Current phenology of *C. geminatus* is largely unknown due to low abundance in recent years. Research in the 1940s and 50s suggested it had generation times of 60 and 56 days in Oregon and California, respectively, with adults emerging in May and September in Oregon (Nielson 1966), which is generally supported by recent research.

Sampling and Testing for X-disease

Material to sample: Submit four five-inch cuttings from the diseased limb(s) including leaves, and **FRUIT STEMS**.

Woody material should be from the previous season or older. Current season growth can have variable pathogen concentrations.

Where to sample: *Trees with symptoms:* Sample from symptomatic limbs. *Trees with no symptoms:* Sample from each leader. *Samples only needed in non-confirmed blocks/ adjoining trees.

When to sample: The week before harvest to mid-August.

Figure 8. To test for X-disease phytoplasma submit four 5-inch cuttings which include pencil sized wood, leaves and fruit stems from symptomatic limbs.

Sample condition: Keep tissue moist and cool (e.g. package with a cold pack). Old or dried tissue is more likely to have false negatives.

Where to send samples:

See labs page http://treefruit.wsu.edu/labs-lchv2-xdp/

Controls

There is no cure and an infected tree will remain infected for the rest of its life. There are no commercial products that have been shown to have an effect on the phytoplasma in scientific studies. Management requires a combination of these four strategies:

1. Pathogen-Free Planting Sources: Replacement trees must be obtained from pathogen-free planting stock. Nursery trees can be free of symptoms and still be infected. **Use certified trees.** Manage your risks – if in doubt, have the material tested before you buy or plant.

2. Identify and Remove Infected Trees: Primary control measures rely on identification and removal of infected trees. Remove infected trees following postharvest treatment for leafhoppers. Infected trees spread the pathogen to neighboring trees by insect vectors or via root-grafting from tree to tree. Treating stumps with herbicide immediately after cutting or injecting into trees before cutting trees (frill treatment) can help to identify adjoining root grafted trees and ensure roots are dead. Several glyphosate products are labeled, see BMPs for Tree Removal. In an early study, orchards where infected trees were removed as soon as they were observed, the disease incidence remained below 2% and decreased over time (Van Steenwyk 1995).

3. Cultural Controls

Kaolin. Recent research has shown that kaolin clay (Surround) applications can reduce leafhopper vector populations in high pressure blocks by 48% percent and reduce leafhopper movement into the canopy (Marshall et al 2024). Kaolin not only deters leafhoppers from orchards it also repels leafhoppers from trees.

Extenday. Extenday can reduce populations in high or low pressure blocks by over 80% (Marshall et al 2024). The effectiveness of Extenday is likely due to removing access to alternative and reproductive hosts in the drive row of the orchards, such as dandelion and other broadleaf weeds.

Grass in drive rows. Planting grass in drive rows can reduce peak leafhopper numbers by approximately 50% compared to weedy drive rows (Northfield unpublished 2023). Leafhoppers cannot survive on grasses (Northfield and Cooper 2020). The most common plants fed on by the leafhopper vectors of X-disease phytoplasma are broadleaf weeds such as dandelion, mallow, lambsquarter, chickweed, knotweed, and plantain (Cooper et al. 2022).

Remove suckers. Root suckers provide easily accessible feeding sites for leafhopper vectors. Root suckers also tend to have higher levels of phytoplasma earlier in the season, likely due to movement of the pathogen from the roots where it overwinters (Wright et al.2022). Removing root suckers may reduce movement of leafhopper vectors into the canopy and reduce transmission (Marshall unpublished data 2023).

4. Monitor and Manage Vectors:

Consider timing. Both leafhopper population numbers and X-disease phytoplasma concentration in the tree are likely to be higher after harvest. When phytoplasma concentration in the tree is higher leafhoppers are more likely to acquire and transfer the pathogen. Concentrate monitoring and management efforts when risk is highest after harvest.

Monitor. Monitor leafhopper populations early and late season, including postharvest in order to manage populations not controlled by your general insect management program.

- Use yellow sticky cards or sweep nets (Purcell and Elkinton 1980).
- Deploy post-harvest.
- Hang at sticky traps 2-4 feet from the orchard floor.
- Place traps on orchard borders, in areas of concern in your block and throughout block. Approx. 1 trap per two acres.
- Monitor every 1-2 weeks.
- Use presence (an average of 1 leafhopper per trap) as a threshold to spray.[i]
- Identify leafhoppers that vector X-disease phytoplasma.

Rotate leafhopper products when populations are present. Manage leafhoppers when they are present – generally after harvest through October based on monitoring. If leafhoppers are present spray rotating between pesticide groups. With the residual of common (conventional) products sticky cards will likely show 21-30 days of control necessitating 4 to 6 after harvest sprays per season.

For example, rotating between:

- **group 3** pyrethroid (e.g. Warrior)
- **group 4** neonicotinoid (e.g. Actara)
- **a new active** group
- back to a group 3 or group 4
- **group 1** (e.g. Carbaryl) late in season when leaf-drop is not a concern.

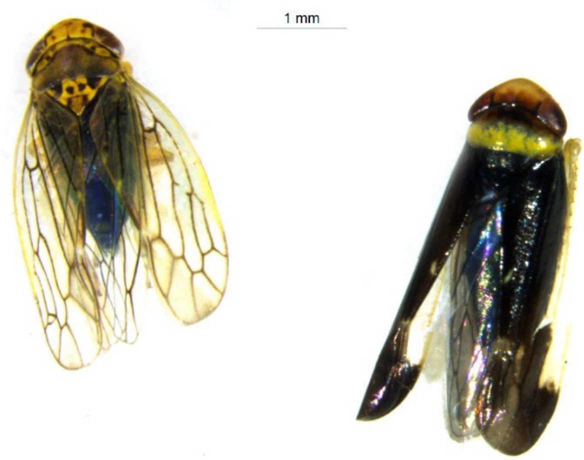


Figure 9. *C. geminatus* left and *C. reductus* right. Look for the face of a pirate with sunglasses and a handlebar mustache on the back of the *C. geminatus*. Look for a distinct yellow stripe on the *C. reductus*. Photo credit T. Northfield, WSU Entomology.

Remember it takes several weeks after feeding on an infected plant for a leafhopper to be able to transmit the phytoplasma. The phytoplasma has to pass through the insect gut, into the 'blood', and to the salivary glands before it can be excreted into a new plant with the saliva. Every two to three weeks sprays should be the shortest interval needed. More frequent sprays will mean you likely run out of legal applications before the end of the season when transmission is likely to be highest. ***See table below.***

5. Manage alternative hosts of the phytoplasma and of the leafhoppers

Reducing broadleaf weeds in orchards can help reduce leafhopper numbers and potentially reduce transmission. Grasses are poor hosts for key vectors and are not a common host for phytoplasma. Apply broadleaf herbicides to the drive row as well as tree row. For example, in a recent study, herbicide applications reduced leafhopper vector numbers by up to 50%, likely by reducing the preferred habitat for the leafhoppers (Northfield unpublished data). Healthy weed-free grass strips compete with broadleaf weeds and supply a non-phytoplasma host environment.

Summary

Finally, control of this disease requires a community-wide effort, what your neighbor does or doesn't do, affects you (and vice versa). The key to ending the current X-disease epidemic relies on reducing the amount of pathogen present in the state. This can only be done by removing infected trees because it is from those trees that the leafhoppers are acquiring and spreading the pathogen.

Table 1. Materials Labeled for Leafhoppers in Cherry in WA

Chemical	Rate per Acre	REI	PHI	MOA	Efficacy	Notes
Actara thiamethoxam	2.75 oz	12 h	14 d	4A	2-4	Actara at 2.75 oz/100gal resulted in 100% mortality of C. reductus leafhoppers 24 hours after treatment 2020 WA trial [Nottingham, 2020]. Actara maintains good control past 24 hours after treatments at 60-80% mortality [Nottingham 2021]. Actara had more than 80% control in 10 CA trials, above 50% in 2 CA trials and 30-50% in 1 CA trial [Van Steenwyk 1988, 1989, 1990, 2002, 2003] Generally thought to be good on nymphs and poor on adults.
Admire Pro imidacloprid	2.8 fl oz	12 h	7 d	4A	1-4	Admire Pro has had mixed success in lab bioassays on C. reductus, from 100% mortality in direct sprays to 15% by residues [Nottingham 2020-2021]. Provado rated as high efficacy on White apple leafhopper in WA trials. Provado provided 8%, 20%, 34%, 69%, 30%, 34%, 51% and 73% control in eight California trials [Van Steenwyk 1988, 2000, 2001]. Many generics now available. E.g. Macho, Asada, Midash Forte.
Agri-Mek SC abamectin	See Label	12 h		6	2-4	Generally thought to be good on nymphs and poor on adults. Rated excellent control White apple leafhopper nymphs West Virginia [Hogmire 1999]. 50% control nymphs and adults New York [Reisig 1995].
Asana XL esfenvalerate	2-5.8 fl oz	12 h	14 d	3A	3-4	Asana resulted in 100% mortality of C. reductus leafhoppers 24 hours after treatment 2020 WA trial [Nottingham 2020]. Asana's efficacy drops to around 50% within 24 hours of treatment [Nottingham 2021]. Asana had 80-90% control in 8 CA trials and 50-79% in 1 CA trial [Van Steenwyk 1987, 1989, 1990, 2002].
Assail 70WP acetamiprid	1.7 oz	12 h	7 d	4A	1-2	Assail had 20, 25, 40 and 52% control in four California trials [Van Steenwyk 2002]. Generally higher efficacy on younger instar nymphs.
Avaunt indoxacarb	6.00 oz	12 h	14 d	22	3-4	Rated good to high efficacy on White apple leafhopper in WA.
Aza-Direct azadirachtin	1-2 pt	4 h	0 d	un	1-3	Aza-direct at 32oz provided 62%, 78% control of white apple leafhopper and 63%, 25% of potato leaf hopper in apples [Wise 2002]. Azadirect 32oz provided 64% of control for potato leafhopper nymphs [Harding 2019].
Azera Azadirachtin, Pyrethrin	56 fl oz	12 h	0		3	Azera (premix of pyrethrins 1.4% and azadirachtin 1.2%) achieved 100% mortality of C. reductus 24 hours after treatment in 2020 WA trial [Nottingham 2020-2021]. Residual control is unknown. Azera 40oz provided 64% of control for potato leafhopper nymphs [Harding 2020].
Beleaf 50SG	2.8 oz	12 h	14 d	29	2-4	In contact bioassays caused 90% mortality 1 day after treatment and 30% mortality to 85% mortality 1 to 2 days after treatment respectively [Northfield 2023, Orpet 2022].

Bexar tolfenpyrad	21 fl oz	12 h	14 d	21A	NR	Additional testing is needed, but an initial lab bioassay showed 65% mortality of C. reductus [Nottingham 2020-2021].
Celite 610 diatomaceous earth	50 lb	none listed			3-4	Celite reduced leafhoppers from colonizing leaves compared to 1% oil by 50% and to untreated checks by 85% in 4 experiments [Nottingham 2021].
Cinnerate cinnamon oil	32 fl oz	none listed	0 d		3	67 % mortality of C. reductus in 2020 WA trial [Nottingham 2020].
Danitol 2.4EC fenpropathrin	18 fl oz	24 h	3 d	3	2-4	It is generally recommended that no more than 2 Danitol 2.4 EC apps per season. Danitol had 68-94% control in four California trials at 0.2 and 0.4 lb AI/a [Steenwyk 1993].
Entrust SC spinosad	8 fl oz	4 h	7 d	5	1-2	32% control of C. reductus in 2020 WA trial [Nottingham 2020].
Malathion 5EC malathion	2.8 pt	12-24 h	3 d	1B	NR	Additional testing is needed, but an initial lab bioassay showed 100% mortality of C. reductus [Nottingham 2020-2021].
Neemix 4.5%L azadirachtin	16.00 fl oz	4 h	0 d	un	1-3	Neemix was not different than the check for controlling of C. reductus [Nottingham 2021]. Neemix at 3.5 and 7 fl oz provided little control compared to the check (Sevin) for white apple leafhoppers for first or second generations [Beers 1995]. Neemix 4.5 at 8 oz provided 67% control potato leafhopper adults 7 days after treatment [Patton 2002].
Sevin XLR Plus carbaryl	3.00 qt	12 h	3 d	1A	2-4	Can cause leaf-drop in Canadian varieties. Use fall only. Sevin had 50-90% in 5 CA. [Van Steenwyk 1988].
Success spinosad	2-2.7 fl oz	4 h	7 d	5	3	Rated as good efficacy on White apple leafhopper in WA.
Surround WP kaolin clay	25-50.00 lb	4 h	0 d		3-4	Kaolin confuses insects where they don't recognize the plants to feed. Two initial post-harvest applications, followed by monthly reapplication of Surround at 50 lb/A reduced leafhopper numbers 20-80% in traps in 2020 WA study [Northfield 2020]. Kaolin reduced leafhoppers from colonizing leaves compared to 1% oil by 50% and to untreated checks by 85% [Nottingham 2021]. Kaolin reduced disease transmission of Pierces disease by glassy winged sharpshooters better than conventional products in one trial [25]. 100% control of white apple leafhoppers [Wise 2002]. Surround + Trilogy 49% control potato leafhopper adults 7 days after treatment [Patton 2002].
Transform sulfoxaflor	2.75 oz	24 h	7 d	4C	3-4	Laboratory bioassays show 85-95% mortality of C. reductus [Nottingham 2021].
TriTek petroleum oil, summer	2 gal	4 h	0 d		3	Oil at 1% reduced leafhoppers in choice tests by 75% [Nottingham 2021] Oil at 2% reduced White apple leafhopper oviposition resulting in fewer nymphs [Fernandez 2001].
Warrior II lambda-cyhalothrin	2.56 fl oz	24 h	14 d	3	NR	95% control potato leafhoppers [Laub 2003]. For potato leafhoppers Warrior II CS at 1.9 fl oz had number 40% lower than untreated control (not sig.) [Kuhar 2009]

Use pesticides with care. Apply them only to plants, animals, or sites listed on the labels. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock. YOU ARE REQUIRED BY LAW TO FOLLOW THE LABEL. It is a legal document. Always read the label before using any pesticide. You, the grower, are responsible for safe pesticide use. Trade (brand) names are provided for your reference only. No discrimination is intended, and other pesticides with the same active ingredient may be suitable. No endorsement is implied.

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Additional Information

X-disease and Little Cherry Virus Scouting and Sampling Guide http://treefruit.wsu.edu/crop-protection/disease-management/western-x/sampling-guide/

Little Cherry Virus http://treefruit.wsu.edu/crop-protection/disease-management/little-cherry-disease/

Symptoms Gallery https://treefruit.wsu.edu/crop-protection/disease-management/western-x/symptoms-gallery/

Nursery Prevention of X-disease Phytoplasma and Little Cherry Virus Recommendations https://treefruit.wsu.edu/nursery-prevention-lcd/

X-disease Vector Gallery https://treefruit.wsu.edu/vector-gallery/

BMPs for tree removal for X-disease and Little Cherry Virus infected trees http://treefruit.wsu.edu/article/bmps-for-tree-removal-for-x-disease-and-little-cherry-virus-infected-trees/

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