X-disease phytoplasma (Western X)

Written by: Scott Harper, WSU Plant Pathology; Tobin Northfield, WSU Entomology; Louis Nottingham, WSU Entomology; Tianna DuPont, WSU Extension. Last updated November, 2020.

X-disease phytoplasma, Little cherry virus 2 (LChV2) and Little cherry virus 1 (LChV1), cause small cherry symptoms often described as ‘X-disease’ and ‘Little Cherry Disease.’ Diseased cherry trees produce small, poorly colored, unmarketable fruit. In peaches, plums, and nectarines X-disease symptoms are typically yellowed curled leaves and shot hole as well as small-deformed fruit. X-disease is present across North America, throughout Washington State, and at epidemic levels in the Columbia River basin, with high incidence in Yakima, Benton, and Franklin counties, and present in Oregon in The Dalles area.

Figure 1 X-disease phytoplasma on Cristalina cherry.

Background

X-disease (Western X) is not a new problem. It was first identified in cherry trees of WA 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.

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 [1]. 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.

WASHINGTON STATE UNIVERSITY EXTENSION

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 bacteria known as a phytoplasma. The X-disease phytoplasma lives and replicates in the vascular phloem of infected trees, interfering with tree growth and development.

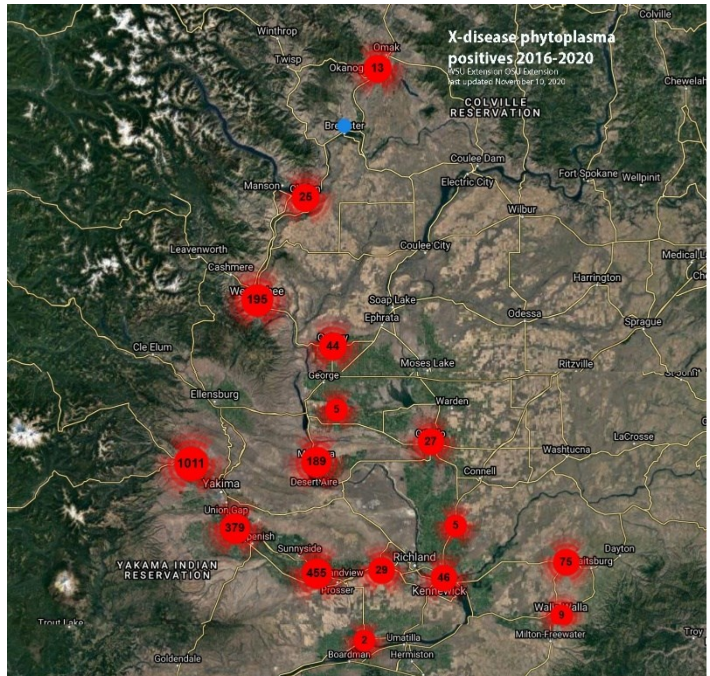

Figure 4. Distribution of documented positive samples for X-disease phytoplasma between 2016 and 2020.

Occurrence

X-disease is present across North America, throughout Washington State, and at epidemic levels in the Columbia River basin, with high incidence from Yakima, Benton, and Franklin counties, and present in Oregon in The Dalles area.


Figure 5. *C. reductus* (left), *C. geminatus* (center) *E. variegatus* (right). Photo credit L. Nottingham, T. Northfield.

Host Range

X-disease phytoplasma infects most *Prunus* species, ex. cherries, peaches, nectarines, almonds, plums, and chokecherry. X-disease phytoplasma also infects weeds: ex. puncture vine, tumble mustard, and flixweed [2].

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*, *Fiebriella florii*, *Scaphytopius acutus*, *Paraphlepsius irroratus*, *Colladonus reductus, E. variegatus* and *Colladonus geminatus* [3, 4]. The two most common in Washington are *C. reductus, C. geminatus*. Low numbers of *S. acutus* and *E. variegatus* were found in 2020 WA survey [5].


Figure 6. *C. montanus* (left), *P. irroratus* (center), *S. acutus* (right). Photo credit Carol Davis (left), Tom Murray (center and right).

Life Cycle of the Organism

The X-disease phytoplasma replicates in the phloem tissue of the tree. It is believed that the phytoplasma either ceases to replicate or dies in the aerial parts of the tree as the branches go dormant during the winter months, but 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

Biology of *C. geminatus* is largely unknown, but research in the 1940s and 50s suggested it had generation times of 52 and 43 days in Oregon and California, respectively, with adults emerging in May and September in Oregon. *C. reductus* biology has been completely unknown until very recently. *Recent research suggests that C. reductus* has three generations in Washington with two occurring after harvest. *C. reductus* fed on a wide range of hosts in feeding trials including mallow, alfalfa, cherry, peach, white clover, and dandelion [6].

Sampling and Testing for X-disease

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

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. See flow chart.

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

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/

Figure 7. To test for X-disease phytoplasma submit four 5-inch cuttings which include leaves and fruit stems from symptomatic limbs.

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 proven in scientific studies to have an effect on the phytoplasma. 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 ensure roots are dead and identify adjoining root grafted trees. 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.

3. Monitor and Manage Vectors:

Consider timing. Both leafhopper populations 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 [4].
- 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 8 *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.***

4. Manage alternative hosts of the phytoplasma and of the leafhoppers: clovers, dandelions, curly dock, bitter cherry, chokecherry. Grasses appear to be poor leafhopper hosts and are not a host for phytoplasma. Apply broadleaf herbicides. Healthy weed-free grass strips compete with broadleaf weeds and supply a non-phytoplasma host environment.

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. Example Products Labeled for Leafhoppers in Cherry in WA*

GROUP	ACTIVE	PRODUCT	RATE PER A**	EFFICACY	NOTES
EXCELLENT (E) 80-90% CONTROL; GOOD (G) 50-79% CONTROL; MODERATE (M) 30-49% CONTROL; POOR (P) <30% CONTROL; NOT RATED (NR).					
3A[I]	Lambda-cyhalothrin 22.8%	Warrior II	2.5 fl oz	NR	95% control potato leafhoppers [7]. For potato leafhoppers Warrior II CS at 1.9 fl oz had number 40% lower than untreated control (not sig.) [8].
3A	Esfenvalerate	Asana XL	2-5.8 fl oz	E	Asana resulted in 100% mortality of *C. reductus* leafhoppers 24 hours after treatment 2020 WA trial [9]. Asana had 80-90% control in 8 CA trials and 50-79% in 1 CA trial [10-14].
3	Fenpropathrin 30.9%	Danitol	18 fl oz	G-E	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 [15].
4A[II]	Imidacloprid		3.2 fl oz	P-E	Provado rated as high efficacy on White apple leafhopper in WA trials [16]. Provado provided 8%, 20%, 34%, 69%, 30%, 34%, 51% and 73% control in eight California trials [10, 13, 17]. Many generics now available. E.g. Macho, Asada, Midash Forte.
4A	Thiamethoxam	Actara	2.5 oz	G-E	Actara at 2.75 oz/100gal resulted in 100% mortality of *C. reductus* leafhoppers 24 hours after treatment 2020 WA trial [9]. Actara had more than 80% control in 10 CA trials, above 50% in 2 CA trials and 30-50% in 1 CA trial [10-14] Generally thought to be good on nymphs and poor on adults.
4A	Acetamiprid 70%	Assail WP	1.7 oz	P-G	Assail had 20, 25, 40 and 52% control in four California trials [13]. Generally higher efficacy on younger instar nymphs.
21A[III]	Tolfenpyrad	Bexar	21 fl oz	NR	
1B	Malathion	Malathion 5EC	2.8 pts		
1	Carbaryl	Sevin	2-3 qt	G-E	**Can cause leaf-drop in Canadian varieties.** Use fall only. Sevin had 50-90% in 5 CA. [11].
6	Abamectin	Agri-mek		M-E	Generally thought to be good on nymphs and poor on adults. Rated excellent control White apple leafhopper nymphs West Virginia [18]. 50% control nymphs and adults New York [19].
22A	Indoxacarb	Avaunt 30DG	6 oz	G-E	Rated good to high efficacy on White apple leafhopper in WA [16].
5	Spinosad	Success	2-2.7 fl oz	G	Rated as good efficacy on White apple leafhopper in WA [16].

***Products with a cherry label and Washington leafhopper data also included. **Assumes 100 gal/A. See label for higher gallonage applications.**

Table 2. Example Certified Organic Products Labeled for Leafhoppers in Cherry in Washington

GROUP	ACTIVE	PRODUCT	RATE	EFFICACY	
EXCELLENT (E) 80-90% CONTROL; GOOD (G) 50-79% CONTROL; MODERATE (M) 30-49% CONTROL; POOR (P) <30% CONTROL; NOT RATED (NR).					
3A	Azadirachtin	AzaDirect	1-2 pt	G	Aza-direct at 32oz provided 62%, 78% control of white apple leafhopper and 63%, 25% of potato leaf hopper in apples [20]. Azadirect 32oz provided 64% of control for potato leafhopper nymphs [21].

3A	Pyrethrins/ Azadirachtin	Azera		E	Azera (premix of pyrethrins 1.4% and azadirachtin 1.2%) achieved 100% mortality of C. reductus 24 hours after treatment in 2020 WA trial [9].Azera 40oz provided 64% of control for potato leafhopper nymphs [21].
3A	Pyrethrin	Pyganic	see label	E	Pyganic (pyrethrins 1.4%) achieved 100% mortality of C. reductus 24 hours after treatment in 2020 WA trial [9]. Pyganic 17 fl oz (3 applications) provided 66% control for potato leafhopper nymphs [21].
UN	Azadirachtin	Neemix	16 oz	P-G	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 [22, 23]. Neemix 4.5 at 8 oz provided 67% control potato leafhopper adults 7 days after treatment [24].
	Kaolin	Surround WP	25-50 lb	E	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 [5]. 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 [20]. Surround + Trilogy 49% control potato leafhopper adults 7 days after treatment [24].
	Mineral oil		2 gal	G	Oil at 2% reduced White apple leafhopper oviposition resulting in fewer nymphs [26].
UNE	Rosemary oil	TetraCURB	56 fl oz	M	52% mortality of *C. reductus* in 2020 WA trial [9].
UNE	Rosemary/ Peppermint oil	Ecotec	See label	NR	Ecotec Ag EC at 24 fl oz provided 40% control of potato leafhopper nymphs [8].
UNE	Cinnamon oil	Cinnerate	60 fl oz	G	67 % mortality of *C. reductus* in 2020 WA trial [9].
5	Spinosad	Entrust	8 oz	P-M	32% control of C. reductus in 2020 WA trial [9].

[i]**Pyrethroid:** Sodium channel modulators. Keeps sodium channels open causing hyperexcitation and sometimes nerve block. Pyrethroids applied at this time can be disruptive to beneficials. Highly toxic to bees; do not spray directly or allow to drift onto blooming crops or weeds where bees are foraging.

[ii] **Neonicotinoids Nicotinic acetylcholine receptor (nAChR) competitive modulators. Bind to the acetylcholine site on nAChRs causing a range of symptoms from hyper-excitation to lethargy and paralysis.**

[iii]**Meti Mitochondrial complex I electron transport inhibitors. Inhibit electron transport complex 1, preventing the utilization of energy by cells.**

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.

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/

X phytoplasma Epidemic http://treefruit.wsu.edu/article/x-phytoplasma-epidemic/

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/

DuPont, S.T., Strohm, C., Molnar, C., Naranjo, R., Bishop, G., **Case studies on tree removal for X-disease phytoplasma and Little cherry virus.** Fruit Matters. August 8, 2020. http://treefruit.wsu.edu/article/tree-removal-case-studies/

DuPont, S.T. **FSA Tree Assistance Program Offers Support for Little Cherry Tree Removal.** Fruit Matters. August 8, 2020. http://treefruit.wsu.edu/article/tap/

Molnar, C., Northfield, T. **Questions and Answers on Insect Vectors of X-disease Phytoplasma.** Fruit Matters. August 5, 2020. http://treefruit.wsu.edu/article/leafhopper_qa/

DuPont, S.T., Northfield, T. **X-disease phytoplasma vector management for 2020.** Fruit Matters. July 7, 2020. Updated Aug 20, 2020. http://treefruit.wsu.edu/article/x-disease-phytoplasma-vector-management-for-2020/

DuPont, S.T., Northfield, T., Naranjo, R., Sallato, B. **Gestión de vectores de fitoplasma X para 2020.** Fruit Matters. July 1, 2020. http://treefruit.wsu.edu/article/gestion-de-vectores-de-fitoplasma-x-para-2020/

Northfield, T. and R. Cooper, **Identifying sources of X disease in cherry orchards.** Washington State Tree Fruit Research Commission Continuing Report, 2020.

Harper, S., A. Wright, and P. McCord, **Understanding little cherry disease pathogenicity.** Washington Tree Fruit Research Commission Continuing Report, 2020.

Nottingham, L. and T. Northfield, **Insecticidal control of leafhoppers in cherries** Washington State Tree Fruit Research Commission Continuing Report, 2020. WTFRC Project: CH-20-103.

Videos

Symptoms of X-disease Phytoplasma in Stone Fruit. Naranjo, R., Molnar, C., DuPont, S.T., Harper, S. Oct, 2020. http://treefruit.wsu.edu/videos/symptoms-of-x-disease-phytoplasma-in-stone-fruit/

Síntomas de Fitoplasma X en Frutas de Hueso. Naranjo, R., Molnar, C., DuPont, S.T., Harper, S. Oct, 2020. http://treefruit.wsu.edu/videos/sintomas-de-fitoplasma-x-en-frutas-de-hueso/

X-disease Vector Management Trials. Marshall, A., Northfield, T., Naranjo, R., DuPont, S.T. Aug, 2020. http://treefruit.wsu.edu/videos/x-disease-vector-management-trials/

X-disease Vector Management. Northfield, T., DuPont, S.T., Marshall, A., Naranjo, R. Aug, 2020. http://treefruit.wsu.edu/videos/x-disease-vector-management/

Manejo de Vectores de Fitoplasma X (X-disease Vector Management). DuPont, S.T., Northfield, T., Naranjo, R. July 2020. http://treefruit.wsu.edu/videos/manejo-de-vectores-de-fitoplasma-x-x-disease-vector-management/

Síntomas de Fitoplasma X y Little Cherry Virus. DuPont, S.T., Harper, S., Wright, A., Bishop, G. June, 2020. http://treefruit.wsu.edu/videos/sintomas-de-fitoplasma-x-y-little-cherry-virus-2/

Symptoms of Little Cherry Virus and X-disease Phytoplasma. DuPont, S.T., Harper, S., Wright, A., Bishop, G. June, 2020. http://treefruit.wsu.edu/videos/symptoms-of-little-cherry-virus-and-x-disease-phytoplasma/

Contacts

Scott Harper, Department of Plant Pathology, Washington State University (509) 786-9230 scott.harper@wsu.edu
Tobin Northfield, WSU Entomology tnorthfield@wsu.edu
Tianna DuPont, WSU Extension (509) 293-8758 tianna.dupont@wsu.edu
Bernardita Sallato, WSU Extension (509) 439-8542 b.sallato@wsu.edu
Ashley Thomson, OSU Extension (541) 296-5494 Ashley.Thompson@oregonstate.edu

References

1. Harper, S., A. Wright, and P. McCord, *Understanding little cherry disease pathogenicity.* Washington Tree Fruit Research Commission Continuing Report, 2020.
2. Jensen, D.D., *Herbaceous host plants of western X-disease agent.* Phytopathology, 1971. **61**: p. 1465-1470.
3. Jensen, D.D., *Comparative Transmission of Western X-Disease Virus by Colladonus montanus, C. geminatus, and a New Leafhopper Vector, Euscelidius variegatus1.* Journal of Economic. Entomology 1969. **62**: p. 1147-1150.
4. Purcell, A.H. and J.A. Elkinton, *A Comparison of Sampling Methods for Leafhopper Vectors of X Disease in California Cherry Orchards.* Journal of economic entomology, 1980. **73**: p. 854-860.
5. Northfield, T. and L. Nottingham, *Field evaluation of leafhopper controls for X disease management.* Washington State Tree Fruit Research Commission Continuing Report, 2020.
6. Northfield, T. and R. Cooper, *Identifying sources of X disease in cherry orchards.* Washington State Tree Fruit Research Commission Continuing Report, 2020.
7. Laub, C.A., S. Tiwari, and R.R. Youngman, *Efficacy of Foliar Insecticides Against Potato Leafhopper.* Arthropod Management Tests, 2003.
8. Kuhar, T.P., *Evaluation of Insecticide Treatments for the Control of Pests of Insects in Snap Beans.* Arthropod Management Tests, 2009. **34**.
9. Nottingham, L. and T. Northfield, *Insecticidal control of leafhoppers in cherries* Washington State Tree Fruit Research Commission Continuing Report, 2020. WTFRC Project: CH-20-103.
10. Van Steenwyk, R.A. and C.F. Fouche, *Control of Mountain Leafhopper on Cherry, 1988.* Insecticide and Acaricide Tests, 1989. **14**(1): p. 60-61.
11. Van Steenwyk, R.A., C.F. Fouche, and D.M. Havens, *Control of Mountain Leafhopper on Cherry, 1987.* Insecticide and Acaricide Tests, 1988. **13**(1): p. 55-55.
12. Van Steenwyk, R.A., D.M. Havens, and R. Freeman, *Evaluation of Trap Types for Two Vectors of Western X Disease: Colladonus montanus and Fieberiella florii (Homoptera: Cicadellidae).* Journal of economic entomology, 1990. **83**(6): p. 2279-2283.
13. Van Steenwyk, R.A., R.M. Nomoto, and J.A. Grant, *Control of Mountain Leafhopper on Sweet Cherry, 2001.* Arthropod Management Tests, 2002. **27**(1).
14. Van Steenwyk, R.A., S.K. Zolbrod, and R.M. Nomoto, *Control of Mountain Leafhopper on Sweet Cherry, 2002.* Arthropod Management Tests, 2003. **28**(1).
15. Steenwyk, R.A.V., et al., *Control of Mountain Leafhopper on Cherry, 1992.* Insecticide and Acaricide Tests, 1993. **18**(1): p. 65-65.
16. DuPont, S.T., et al., *Crop Protection Guide for Tree Fruits in Washington*. 2020, Washington State University.
17. Grant, J.A. and R.A. Van Steenwyk, *Control of Mountain Leafhopper on Sweet Cherry, 1999.* Arthropod Management Tests, 2000. **25**(1).
18. Hogmire, H.W. and T. Winfield, *Insecticide and acaracide evaluation against leafhopper and mite pests 1999.* Arthropod Management Tests, 1999.
19. Reissig, H., D.H. Dunham, and C. Smith, *Apple, Tests of insecticides against White apple leafhoppers, New York.* Arthropod Management Tests, 1995. **21**: p. 45.
20. Wise, J.C., K. Schoenborn, and L.J. Gut, *Season Long Broad Spectrum Insect Control.* Arthropod Management Tests, 2002.
21. Harding, R.S., B.A. Nault, and A. Seaman, *Potato Leafhopper Control in Snap Bean With Insecticides Allowed for Organic Production, 2019.* Arthropod Management Tests, 2020. **45**(1).
22. Beers, E.H., *Effect of Rate and Timing of Biorational Materials for Control of First Generation White Apple Leafhopper Nymphs.* Arthropod Management Tests, 1995. **21**(5).
23. Beers, E.H., *Effect of rate and timing of biorational materials for control of second generation white apple leafhopper nymphs, 1995*. Arthropod Management Tests, ed. A.K. Burditt, Jr. Vol. 21. 1996: Entomological Society of America {a}, 9301 Annapolis Road, Lanham, Maryland 20706, USA. 6-7.
24. Patton, T.W. and G.P. Dively, *Control of Potato Leafhopper Using Organic and Conventional Insecticides 2002.* Arthropod Management Tests, 2002.
25. Tubajikaa, K.M., et al., *The effects of kaolin, harpin, and imidacloprid on development of Pierce's disease in grape.* Crop Protection, 2007. **26**: p. 92-99.
26. Fernandez, D.E., et al., *Mineral oil inhibition of white apple leafhopper (Homoptera : Cicadellidae) oviposition.* Journal of Entomological Science, 2001. **36**(3): p. 237-243.