The Journal of Extension

Volume 60 | Number 4 Article 17

12-19-2022

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Recommended Citation

Molnar, C., DuPont, T., & Thompson, A. (2022). Estimated Impact of X-disease and Little Cherry Disease in Washington and Oregon from 2015 to 2020. *The Journal of Extension, 60*(4), Article 17. https://doi.org/10.34068/joe.60.04.17

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Cover Page Footnote

We would like that thank B.J. Thurlby, Tobin Northfield and Bernadita Sallato for reviewing drafts of this article and for funding from the Washington Tree Fruit Research Commission. We also want to thank everyone who helped with and shared data for this study.

JOURNAL OF Extension Research in Brief Volume 60, Issue 4, 2022

Estimated Impact of X-disease and Little Cherry Disease in Washington and Oregon from 2015 to 2020

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Abstract. X-disease phytoplasma and little cherry virus 1 and 2 have resulted in substantial loss of stone fruit acreage in Washington and Oregon. The extent and financial impact on the industry was not previously known. A Washington and Oregon State University survey documented 238,856 trees equivalent to 974 acres of sweet cherries removed due to X-disease and little cherry disease between 2015 and 2020. 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 an estimated $115 million.

INTRODUCTION

X-disease phytoplasma, Little cherry virus-1 (LChV-1), and Little cherry virus-2 (LChV-2) cause small, poorly colored, unmarketable fruit in cherries (Jelkmann & Eastwell, 2011; Uyemoto & Kirkpatrick, 2011). In peaches, plums, and nectarines, X-disease phytoplasma symptoms are typically yellowed curled leaves with shot holes as well as small, deformed fruit (Stoddard, 1934). Both pathogens are transmitted by all types of grafting and vectored by insects. X-disease phytoplasma is vectored by several species of leafhoppers (Purcell & Elkinton, 1980), while LChV-2 is vectored by grape and apple mealybugs (Mekuria et al., 2013; Raine et al., 1986). LChV-1 has no known vector, but it can be spread through all types of grafting (Tahzima et al., 2019). Once infected, trees cannot be cured and will continue to be infected the rest of their lives. Disease symptoms progress over time, becoming more severe over the course of several years (Uyemoto & Kirkpatrick, 2011). X-disease, caused by X-disease phytoplasma *Candidatus phytoplasma* pruni, formerly referred to as Western X and Buckskin disease, was first documented on peaches in 1933 in Connecticut and is currently present throughout North America, where it can infect most *Prunus* species and numerous herbaceous weeds (Davis et al., 2013).

Outbreaks of little cherry disease caused by LChV-2 occurred in British Columbia, Canada between 1938-1979, where it devastated the Canadian cherry industry (Theilmann et al., 2004). In Washington in the 1940s to 1950s, a similar outbreak occurred that resulted in significant acreage removal (Blodgett and Wright, 1948). California was affected by a severe outbreak of X-disease, at the time called Cherry Buckskin, in the 1970s and 1980s (Purcell et al., 1987). In past outbreaks, effective control has required prompt removal of infected trees with monitoring and control of insect vectors a secondary but critical factor (Uyemoto et al., 1998).

X-disease and little cherry disease are a major concern to stone fruit growers in the Pacific Northwest. On average, the Pacific Northwest region produces 84% of fresh cherries in the United States (Northwest Horticultural Council, 2021C). The Washington tree fruit acreage includes 179,146 acres of apples, 20,965 acres of pears, 42,198 acres of cherries, and 2,907 acres of stone fruit (USDA, NASS). Cherry and stone fruit production in Washington is concentrated in nine counties: 5,654 acres of cherries in Chelan, 3,127 in Douglas, 3,265 in Okanogan, 7,976 acres in Grant, 348 in Adams, 4,616 in Benton, 2,966 in Franklin, 12,078 in Yakima, and 1,058 in Klickitat. The Oregon tree fruit industry includes 12,000 acres of cherries, 5,000 acres of apples, 13,900 acres of pears, and 1,554 acres of stone fruit. Of all Oregon counties, 14 have sweet cherry acreage, 93% of which are in Wasco County (9,294 acres) or Hood River County (1,905 acres) (USDA, NASS).

The current outbreak of stone fruit diseases in Washington and Oregon began in 2010 with a surge of LChV-2, followed by an outbreak of X-disease in South-central Washington in 2015 (Mekuria et al., 2014; Villamor & Eastwell, 2019; Harper, Bixby-Brosi et al., 2020). X-disease has continued to spread and is at epidemic levels in the Columbia River basin, with high incidence in Yakima, Benton, and Franklin counties in Washington State and lower presence in Washington's northern counties such as Okanogan County. In

Oregon, X-disease and little cherry disease are both present in Wasco County (Harper, Northfield et al., 2020). LChV-2 is present throughout Washington at lower levels, though LChV-1 is rare (Harper, Bixby-Brosi et al., 2020). Washington State University Extension currently recommends removing trees infected with either of the little cherry viruses or X-disease phytoplasma, since no treatments have been shown to cure or treat X-disease or the little cherry viruses. Leaving infected trees in blocks contributes to the spread of the disease. If more than 20% of a block is infected, removal of the block is generally necessary due to the latent infections—which will continue to become symptomatic and eventually reduce yield below profitable levels (Harper, Northfield et al., 2020).

Growers in Washington and Oregon have responded to X-disease and little cherry disease infections with aggressive tree removal to slow their spread. However, the extent of tree removal and the resulting economic loss was not previously known. This survey's objective was to document trees removed and acreage affected due to X-disease and little cherry disease in Washington and Oregon and to estimate the diseases' financial impact on the Pacific Northwest cherry industry. This information is important to help growers and Extension staff better understand the severity of X-disease and little cherry disease and respond accordingly (Shields & Deller, 2003). Orchardists and consultants identified the need for an accurate quantitative measure of economic impact in adopting best management practices (DuPont, 2020). This information will help researchers demonstrate the potential financial impact of little cherry disease and X-disease to growers in order to encourage aggressive management and prevent the loss of the cherry and stone fruit industry in the Pacific Northwest and the communities they support. Current information about the management, spread, impact, and biology of these pathogens is available at the WSU Tree Fruit extension website <treefruit.wsu.edu>.

METHODS

Washington State University (WSU) and Oregon State University (OSU) Extension specialists, in collaboration with stakeholders, developed an X-disease and little cherry disease impact survey (See Appendix). This survey was designed to capture tree and acreage loss from 2015 to 2020 in Washington and Oregon. The survey asked growers to indicate the number of individual cherry, peach/nectarine, and plum trees and acreage removed due to little cherry disease or X-disease. For each block reported, growers were asked to identify the variety of tree, tree density, year removed, and county in which the block was located. The survey also asked growers to report the total acreage of cherry, peach/nectarine, and plum fruit they manage as well as their role in the operation (owner, manager, consultant, or other). Data were collected anonymously via Qualtrics between March 7, 2020, and January 29, 2021. Individual contacts known to have removed trees were also interviewed by Extension personnel. The survey was shared via several methods: emails to related committees and groups, promotion on the treefruit.wsu.edu website, contacts gathered by the WSU Extension, and promotion on social media posts.

Survey organizers tabulated responses to obtain total acreage and tree removal numbers by region and county. When only acreage removed or trees removed were supplied by survey respondents, rather than both, the grower reported tree density, or the study authors used the statewide average of 270 trees per acre to calculate missing acreage or tree number values (Mertz et al., 2017). Other missing values were treated as not determined (ND). Domestic red cherries constitute 90-93% of WA and OR cherry sales. Because of this, red cherry prices were used for the prices of all cherries (NW Cherry Growers 2022). Cherries constituted 92% of acres removed, so the following economic analysis focuses on cherries. Estimates of financial loss were calculated using Equations 1 and 2 and assumptions from Table 1.

$$= [(T_{20} \times Y_{20}) + (T_{19} \times Y_{19}) + (T_{18} \times Y_{18}) + (T_{17} \times Y_{17}) + (T_{16} \times Y_{16}) + (T_{15} \times Y_{15})] \times P_{20} \quad (1)$$

Where:
T = Trees removed in a given year (according to survey data)
Y = average lbs per fruit tree from lbs per fruit acre statewide average (United States Department of Agriculture (USDA, NASS), 2015-2019) at 270 trees per acre (Mertz et al., 2017) (Table 1). In 2020 14,000 lbs fruit acre^{-1} was used (Galinato & Gallardo, 2015).
P = Wholesale price dollars lb^{-1} from Freight on Board (FOB) for domestic red cherries in a 20 lb box for a given year (Washington State Tree Fruit Association (WSTFA), 2019).

Subscripts in T, Y, and P are used to specify the year for that data: 20=2020, 19=2019, 18=2018, 17=2017, 16=2016 and 15=2015.

Lost revenue and establishment costs to growers was calculated based on Galinato and Gallardo (2015) using Equation 2.

$$= acres\ removed \times (E + R \times 6\ years) \quad (2)$$

Where:
E = $64,095 establishment costs per acre
R = $9,000 average net returns per year per acre

Table 1. Assumed Specifications for Economic Calculations

year	*average lbs fruit acre-1* †	*average lbs fruit tree-1* ‡	$ per box §	$ per lb
2015	12040	44.59	$39.71	$1.99
2016	10800	40.00	$41.85	$2.09
2017	13120	48.59	$34.00	$1.70
2018	12240	45.33	$35.00	$1.75
2019	11940	44.22	$39.40	$1.97
2020	14000	51.85	$52.80	$2.64

† lbs fruit acre-1 statewide average (USDA, NASS 2015–2019).

‡ Assumes 270 trees per acre.

§ Freight on Board (FOB) for domestic red cherries in a 20 lb box for a given year (WSTFA, 2019).

Table 3. Trees and Acres Removed Due to X-disease and Little Cherry Disease Between 2015 and 2020 in Washington and Oregon

Year	Cherry		Peach, Nectarine, Plum, and Apricot	
	Trees lost	Acreage lost	Trees lost	Acreage lost
2015	63,720	236		
2016	2,028	19		
2017	3,410	10		
2018	10,274	38		
2019	53,955	221	1,340	7
2020	105,468	451	31,742	74
Total	**238,856**	**974**	**33,082**	**81**

Table 2. Respondent Demographics

Role	Number of responses
Owner/operator	61 (74%)
Manager	10 (12%)
Consultant	4 (5%)
Other	4 (5%)
ND†	3 (4%)

† ND=Not Determined.

RESULTS

DEMOGRAPHICS

A total of 81 respondents completed the survey. Seventy-four percent of respondents were owners/operators, 12% were managers, 5% were consultants, and 5% other (Table 2). Responses represented approximately 15,420 acres, or 26% of the 58,695 acres of cherry currently in production in Washington and Oregon (USDA, NASS). This number includes 764 acres of orchard blocks with no trees removed, or 1.3% of the total cherry acreage. On average, respondents managed 190.4 acres of any kind of stone fruit. Seventeen percent of respondents managed less than 30 acres, 37% managed 31-140 acres, 20% managed 141-999 acres, and 5% managed more than 1,000 acres.

TREES, ACRES AND BLOCKS REMOVED

Since 2015, a total of 238,856 cherry trees—or the equivalent of 974 acres—and 33,082 peach, nectarine, plum and apricot trees—the equivalent of 81 acres—have been removed as a result of X-disease (Table 3).

Of the 209 blocks reported in this survey that had trees removed due to X-disease or little cherry disease, 186 had cherry trees and nine had stone fruit trees (Table 4). Reported blocks had as few as two trees removed or as much as 100% of the block removed. Yakima County had the largest number of blocks with trees removed (33.2%). Other counties in Washington with many blocks from which trees were removed are Chelan (16.8%), Grant (9.2%), and Douglas (10.2%). Nearly 8% (7.7%) of the blocks that reportedly had trees removed are in Wasco County, Oregon.

Counties that suffered the heaviest losses as measured by percentage of removed trees and acres were Chelan County

Table 4. Distribution of Cherry and Stone Fruit Blocks Removed, by County

County	Number of Respondents	Number of blocks with removed trees	% of blocks with trees removed
Benton	4	9	4.6
Chelan	11	33	16.8
Douglas	6	20	10.2
Franklin	3	9	4.6
Grant	8	18	9.2
Klickitat	1	2	1
Okanogan	1	1	0.5
Umatilla, OR	1	0	
Wasco, OR	5	15	7.7
Yakima	21	65	33.2
ND†	20	23	12.2
Total	**81**	**195**	

Note. When respondents listed blocks in multiple counties, the first block they submitted is used as the listed county here. Counties are in Washington state unless otherwise stated.

† ND=Not Determined.

(6.28% of total cherry trees removed, 5.6% of total acreage removed), Grant County (1.7% of total cherry trees removed, 2.56% of total acreage removed), and Yakima County (2.12% of total cherry trees removed, 2.89% of total acreage removed) (Table 5, Figure 1).

Table 5. Distribution of Trees and Acres Removed due to X-disease and Little Cherry Disease by County

County	Cherry		Peach, Nectarine, Plum	
County	Trees	Acres	Trees	Acres
Benton	14,310	31		
Chelan	89,109	337		
Douglas	3,607	13		
Franklin	5,755	41	27,773	70
Grant	19,803	118	5	0.01
Klickitat	5,005	18		
Okanogan	2	0.01		
Wasco, OR	2,616	10		
Yakima	92,485	381	5,304	11
NA	6,165	24		
Total	**238,856**	**974**	**33,082**	**81**

Note. Counties are in Washington State unless otherwise stated.

AGE AND CULTIVAR OF TREES REMOVED

The removed trees and blocks were most commonly Bing, Rainier, Santina, and Skeena cultivars (Table 6). Skeena blocks reported in this survey were primarily older, low-density blocks, resulting in relatively fewer trees removed but a larger affected acreage. Most trees removed were production age (Table 7).

ECONOMIC IMPACT

The loss of 238,856 trees due to X-disease and little cherry disease reported in this survey resulted in over $30,119,188 lost in cherry sales to the industry in 2020 and more than $65,047,833 in the past five years (Table 8). The impacts of tree removal are long lasting due to a 7-year re-establishment period. Re-establishing orchards after the removal of 974 acres of cherries will cost growers $115,043,234, assuming average establishment costs of $64,095 per acre and average net revenue of $9,000 per acre per year, the equivalent of $118,095 per acre in establishment and lost revenue (Table 9).

DISCUSSION

X-disease and little cherry disease are of major concern to stone fruit producers in the Pacific Northwest. Experts rec-

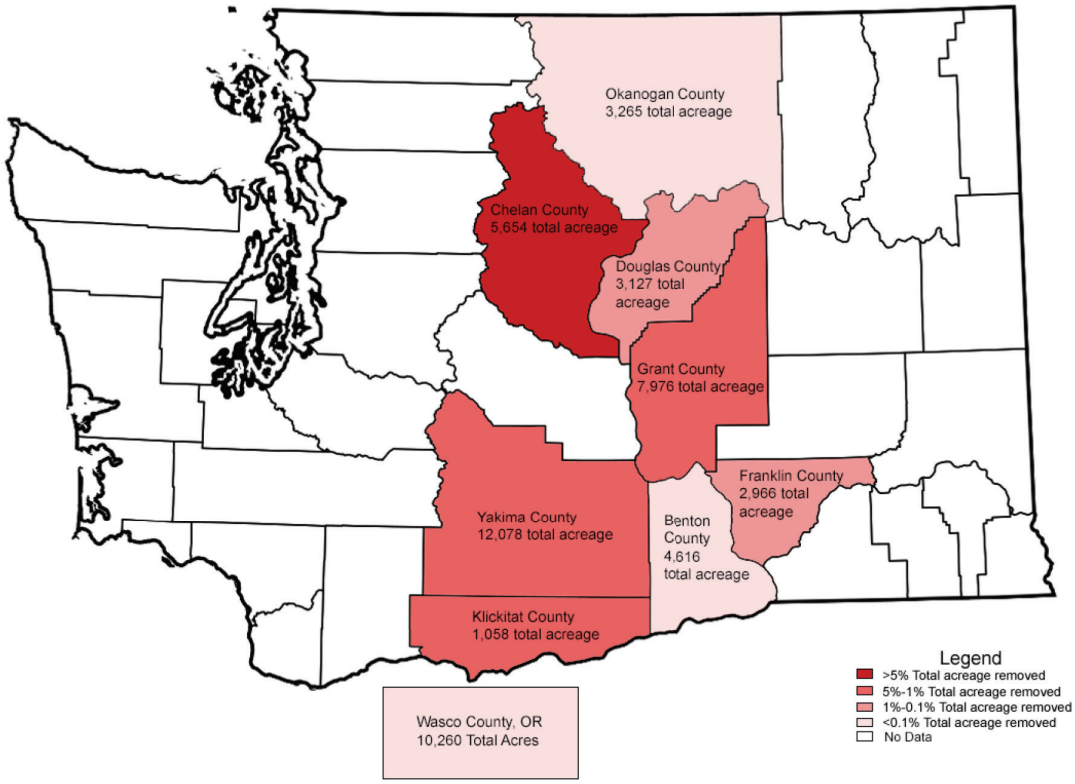

Figure 1. Sweet cherry trees and acreage removed due to X-disease and Little Cherry Disease from 2015 to 2020¥. ¥Total acreage by county from USDA National Agricultural Statistics Service sweet cherry acreage bearing and non-bearing (USDA, NASS). Hood River County, Oregon and Adams County, Washington also produce significant sweet cherry acreage (1,905 acres and 348 acres respectively) but reported no tree loss.

Table 6. Cultivar Distribution of Cherry Trees Removed due to X-disease and Little Cherry Disease

Cultivar	Blocks	Trees	Acreage
'Benton'	7	2,149	10
'Bing'	30	33,432	149
'Chelan'	11	7,949	30
'Coral Champagne'	3	160	0.5
'Cristalina'	6	4,964	14
'Early Robin'	3	5,278	20
'Glory'	1	50	0.06
'Lake Cherry'	1	8,514	17
'Lapin'	7	1,058	7
'Rainier'	18	19,890	64
'Regina'	1	4	0.01
'Santina'	8	20,811	35
'Skeena'	11	12,028	115
'Sweetheart'	15	5,793	45
'Tieton'	2	5,098	14
Mixed cherry plantings	6	1,556	16
ND†	56	110,123	438

† ND=Not Determined.

Table 7. Age Distribution of Cherry Trees Removed due to X-disease and Little Cherry Disease

Estimated age of block	Number of Blocks	Number of Trees	Acreage Removed
1-3 leaf	1	10	0.02
4-6 leaf	13	20,325	43.83
7-10 leaf	24	22,914	112.53
11-20 leaf	49	50,660	205.99
21-30 leaf	20	14,899	100.42
31+	14	6,062	35.51
ND†	65	123,987	475.86

† ND=Not Determined.

ommend removing trees within the year that symptoms are detected. However, tree removal comes at a high cost to growers and a substantial loss to the industry overall. This study found that these diseases have cost growers in Washington and Oregon at least $65 million in sales since 2015 and will cost over $115 million in lost revenue and establishment costs over the 7-year re-establishment period. Counties that suffered the heaviest losses were Yakima, Chelan, and Grant counties in Washington state and Wasco County in Oregon. In other areas, scouting and aggressive tree removal are also necessary to slow the spread of the problem. Graft-transmissible diseases, like X-disease and little cherry disease, are of great concern to tree fruit growers because of the long-term economic impact associated with costly management programs (Fuchs et al., 2021). While past outbreaks have eventually subsided, they resulted in heavy reductions in acreage or a significant decrease in the stone fruit industry in some locations (Blodgett & Wright, 1948; Purcell et al., 1987; Theilmann et al., 2004). Outbreaks of other similarly-behaving diseases, such as the plum pox virus (PPV) in Pennsylvania, were eradicated through intensive efforts of disease monitoring and immediate destruction of infected trees, resulting in the destruction of 1,800 acres of commercial stone fruit orchards over the course of 10 years (Welliver et al., 2014). While the outbreak of PPV took place under very different circumstances, the outcome still highlights the severity of graft-transmissible diseases and the importance and effectiveness of proper management.

The survey responses are representative of the cherry- and stone fruit-producing counties in Washington and Oregon but may be skewed by an over-representation of larger producers. Respondents managed an average of 190 acres of stone fruit. This is larger than the average, which is 19 acres of cherries per operation in Oregon and 24 in Washington (USDA, NASS). In Oregon, only Wasco County reported tree removal. This is not surprising, as 78% of the cherry acreage in Oregon is in Wasco County (USDA, NASS). Cherry acreage removed in Washington coincides with the distribution of cherry production in the state. The central Washington counties—Okanogan, Chelan, Douglas, Grant, Yakima, Benton, Franklin, and Klickitat—account for 97.5% of the bearing acreage in Washington (Galinto, 2015). Of 974 cherry acres removed, 39% were in Yakima County Washington, the Washington county with the largest acreage of cherries (Figure 1; USDA, NASS). Fourteen percent of Washington's cherry acreage is in Chelan County, but 35% of the reported acreage removed was in Chelan County.

The estimates reported in this study are based on a self-selected sample of producers and may underestimate actual trees and acres removed. However, the current sample set is relatively large and includes respondents who collectively manage 15,420 acres, approximately 26% of the total cherry acreage currently in production in Washington and Oregon (Table 2; USDA, NASS). Sampling was not random, so the data cannot be scaled to estimate losses from all cherry acres. During the 2021 WSU Tree Fruit Days conference, researchers estimated a similar quantity of removed acreage using the results from a live survey conducted during the conference. In the conference's survey, approximately 37% of managers responded saying they had removed trees within the last 2 years (N=81) (DuPont et al., 2021, unpublished data). Washington and Oregon have approximately 58,695 acres of sweet cherries (USDA, NASS). The current dataset reports removal of 974 acres, or 6% of the 15,420 acres represented. If we scale those numbers and remove 6% of their

Table 8. Economic Impact of Tree Loss to X-disease and Little Cherry Disease on Cherry Sales

Year	Trees removed	Fruit loss (lbs) from trees removed in current year	Reduced boxes from trees removed in current year	Reduced boxes from trees removed to date	FOB ($/box)	Reduced cherry sales ($)
2015	63,720	2,841,440	142,072	142,072	39.71	5,641,679
2016	2,028	81,120	4,056	146,128	41.85	6,115,457
2017	3,410	165,701	8,285	154,413	34.00	5,250,043
2018	10,274	465,772	23,289	177,702	35.00	6,219,558
2019	53,955	2,386,021	119,301	297,003	39.40	11,701,908
2020	105,468	5,468,729	273,436	570,439	52.80	30,119,188
Total	**238,856**	**11,408,783**	**570,439**	**NA**	**NA**	**65,047,833**

Table 9. Economic Impacts to Cherry Growers from Orchard Establishment Costs and Lost Revenue per Acre of Orchard Removed

County	Acreage removed	Lost revenue and replanting costs ($)
Benton	31	3,674,848
Chelan	337	39,835,571
Douglas	13	1,481,886
Franklin	41	4,891,222
Grant	118	13,933,916
Klickitat	18	2,177,425
Okanogan	0.01	590
Wasco, OR	10	1,191,009
Yakima	381	44,963,626
NA	24	2,893,064
Total	**974**	**115,043,157**

Note. Counties are in Washington State unless otherwise stated.

Table 10. Economic Impacts of Trees Removed Due to X-disease and Little Cherry Disease on Reduced Cherry Sales by County Between 2015 and 2019

County/Location	Trees removed	Loss to industry in cherry sales ($)
Benton	14,310	$1,961,763
Chelan	89109	$39,846,343
Douglas	3,607	$615,444
Franklin	5,755	$787,727
Grant	19,803	$2,716,904
Klickitat	5,005	$1,020,007
Okanogan	2	$274
Wasco, OR	2616	$467,941
Yakima	92,485	$16,757,100
NA	6,165	$874,330
Total	**238,856**	**$65,047,833**

Note. Counties are in Washington State unless otherwise stated.

acres from the entire 58,695 acres in the region, the result is 1,303 acres removed: a similar number to that reported in this study, suggesting that our survey responses may be representative despite our small survey size. The total impact of X-disease on other stone fruit, such as peaches, nectarines, plums, and apricots, is less certain due to significantly less acreage in either state and few survey responses.

This study does not attempt to account for losses in production from infected trees that were not removed. Infected trees can still produce some sellable fruit for several years, though portions of the tree are not pickable (Harper, Bixby-Brosi et al., 2020; Harper, Northfield et al., 2020; Uyemoto & Kirkpatrick, 2011). Infection reduces the overall yield of the block and contributes to the spread of X-disease phytoplasma and little cherry virus pathogens to nearby blocks (Harper, 2020, personal communication). The financial impact of little cherry disease and X-disease would be greater if yield reductions were also considered.

While multiple pathogens are involved in these diseases, we did not ask growers to differentiate between them when reporting tree removal data. The only accurate method to differentiate between X-disease phytoplasma, LChV-1, and LChV-2 are molecular tests (Beaver-Kanuya et al., 2019; Villamor & Eastwell, 2019). Once the symptoms of infection are visible, trees are often removed without testing for the specific infection; experts recommend tree removal for

both pathogens. X-disease is more often encountered in the Yakima valley (consisting of Yakima and Benton counties), while LChV-2 is more frequently seen in the Wenatchee area of Chelan and Douglas Counties (Harper, Bixby-Brosi et al., 2020; Harper, Northfield et al., 2020). As shown in Figure 1 and Table 4, both areas had significant tree and acreage removal. This suggests that both diseases are present and are of concern to growers. Infections can take several years to become noticeable, so growers will likely have to continue to remove trees and manage vectors for several years before disease epidemics abate.

CONCLUSION

Washington and Oregon are suffering outbreaks of X-disease and little cherry disease, resulting in the removal of substantial stone fruit acreage. In this survey, we documented removal of 238,856 cherry trees (974 acres) and 33,082 peach, nectarine, plum and apricot trees (81 acres) due to X-disease or little cherry disease from 2015 to 2020. Tree removal resulted in over $30,119,188 worth of sales lost to the cherry industry in 2020 alone and more than $65,047,833 in the past five years. Removal of 974 acres of cherries will cost growers $115,043,234 to re-establish their orchards. A summary of these results, as well as up-to-date information on these diseases, is available at the WSU Tree Fruit Extension website and on a recently released "Little Cherry Scouting Guide" app for Apple and Android. These results provide a baseline for the damage that little cherry disease and X-disease have caused to the stone fruit industry in the Pacific Northwest and should help Extension agents and consultants demonstrate the importance of proper management and the potential financial impact. Aggressive management techniques—including tree removal, vector management, and planting trees derived from pathogen-tested mother plants—is critical to slow pathogen spread and reduce economic losses. Researchers should look further into the biology, management, and prevention of X-disease and little cherry disease to provide suggestions for improved management strategies.

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APPENDIX. X-DISEASE, LITTLE CHERRY DISEASE IMPACT SURVEY

In order to provide data to build awareness, justify grants, assistance and county funds disbursement WSU Extension is surveying little cherry virus and X phytoplasma impacts. Please help us by answering the following questions. If we can accurately estimate the trees and acres removed, we can estimate economic impact which will be important to convince local and state governments to provide assistance as well as federal granting agencies. If you responded to 2019 survey, please do not include tree removal already reported.

1. How many acres/trees did you have to remove to X phytoplasma or little cherry virus (little cherry disease, X-disease)?

	Cherry			Peach/Nectarine/Plums			County	Tree Density	Variety	Age	Year removed
Block	individual trees	acres	percent trees in block or whole block	individual trees	acres	percent trees in block or whole block	name of county where orchard block is located	trees per acre		average age of trees	What year were trees removed?
1											
2											
3											
4											
5											
6											

**It is fine to report total vs by block when blocks are in the same county.

2. How many acres do you manage? (Optional. This question is just to give us an idea of the percent of acres surveyed).

	Number of acres	
	organic	conventional
Cherry		
Peach/ Nectarine		
Plum		

3. Choose your role

Owner/operator Orchard manager Consult Other