FINAL PROJECT REPORT **YEAR: 4 of 3 (+1 of no cost extension)**
Project Number: PR14-104

Project Title: Fall and summer pruning to control vigor and psylla in Anjou pear

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Cooperators: Sara Serra (WSU/TFREC)

Total Project Request: **Year 1**: $72,707 **Year 2**: $71,589 **Year 3**: $71,170

Other funding sources:

Agency Name: USDA/ARS
Amt. awarded: Harvest and postharvest quality analyses conducted by Jim Mattheis to be supported with base USDA, ARS funds.

WTFRC Collaborative Expenses: None

Budget
Organization Name: WSU **Contract Administrator:** Katy Roberts/Joni Cartwright
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Item	**2014**	**2015**	**2016**	**2017 (NCE)**
Salaries[1]	36,480	37,939	39,456	0
Wages[2]	11,440	11,898	12,374	0
Benefit[3]	14,130	14,695	15,283	0
Travel[4]	757	757	757	0
Goods and Services[5]	9,900	6,300	3,300	0
Total	72,707	71,589	71,170	0

Footnotes:
[1] Salary for a new hire Research Intern (Musacchi), a Research Intern (Beers).
[2] One non-Student temporary for 13 wks: 40/wk at $11/hr (Musacchi) and one non-Student temporary for 13 wks: 40/wk at $11/hr (Beers).
[3] Benefits at 9.7% (Musacchi and Beers).
[4] 676 miles/year for domestic travel to go to the orchard (Musacchi) and 676 miles/year for domestic travel to go to the orchard (Beers).
[5] Fruit mineral analyses, data loggers, light bar, laboratory supplies for fruit quality analyses (Musacchi).

OBJECTIVES

1. *Control vigor through pruning practices in a mature Anjou orchard while maintaining yield and quality, and reduce psylla densities throughout the tree.*

SIGNIFICANT FINDINGS

Vigor control and vegetative measurements

- Regardless of rootstock, more material was removed in 2017 winter pruning than 2016 fall.
- OHF97, OHF69, and OHF87 did not differ in weight pruned in winter 2017, while OHF87 reported the least amount of material removed in 2016 fall pruning respect to the other two rootstocks.
- Trunks of winter pruned trees were significantly larger than fall pruned trees for all rootstocks and, OHF97 trunks were the largest and OHF87 were the smallest in fall pruning only.
- There was no significant difference between annual trunk growth of trees pruned in different seasons.
- OHF87 had the most fruit set per branch and OHF69 had the least when considering both pruning treatments together (in 2016), while no differences in 2017 between rootstocks.

Yield (2016+2017) and fruit quality (2015)

- In the 2016 harvest, winter pruned trees had significantly more and heavier fruit, higher yield efficiencies and crop loads, but more fruit with sunburn and cork than trees pruned in the fall.
- There was no significant difference between the three rootstocks for productivity, average fruit weight, and incidence of sunburn and cork; however, OHF97 had significantly lower yield efficiencies and crop loads than the semi-vigorous rootstocks.
- In 2017, fall pruned trees produced significantly more fruit with a higher yield/ tree and higher yield efficiency and crop load than winter pruned trees.
- The average fruit weight for winter pruned trees was only 6 g higher than fall pruned trees.
- After 7 months, fruits from the winter pruning treatment were riper (by I_{AD} index) than fall+summer fruit: they lost significantly more weight in storage, ripened significantly faster and were less firm (only significant at 5 months) than fall+summer fruits.
- Winter pruned fruit from 2015 had more cork than fall+summer fruit after 5 and 7 months of storage. However, there were no differences in calcium content for pear tissue after 5 or 7 months of storage.

Psylla and Mite Densities

- Adult psylla densities were low in mid-April (2-3/tap) and remained low through early July; however, much higher numbers (8-10/tap) were found just before harvest in mid-September Nymph densities were also low (<0.05/leaf) except for a peak (0.2/leaf) in early July. Spider mites and predatory mites were low on all counts.
- No differences in seasonal average densities for mites or psylla were found among pruning treatments or rootstocks.
- For the first time in this experiment, fruit damage by psylla was significantly lower in the fall-pruned trees than in the standard (winter) timing. Psylla damage among rootstocks was OHF69>OHF97>OHF87. All fruit examined had russeting resembling rust mite damage, despite the absence of rust mites in leaf brush counts.

RESULTS AND DISCUSSION

Vigor and vegetative measurements

Regardless of rootstock, significantly (2.5 times) more material was removed in winter pruning than in fall in both 2015-2016 and 2016-2017 (Fig. 1). Among rootstocks, OHF97, OHF69, and OHF87 did not differ in weight pruned in the 2017 winter treatment (average. 13.7 kg/tree, Fig. 1 and 2) confirming the 2016 trend (Fig. 2), while OHF 87 reported a significant lower amount of material removed in the 2016 fall pruning in comparison to the other two rootstocks (Fig. 2). There was no significant difference between trunk growth of trees pruned at different times (Fig. 1), however OHF97 trunks grew the most and OHF87 trunks the least in 2016, while no difference reported for 2017 (data not shown).

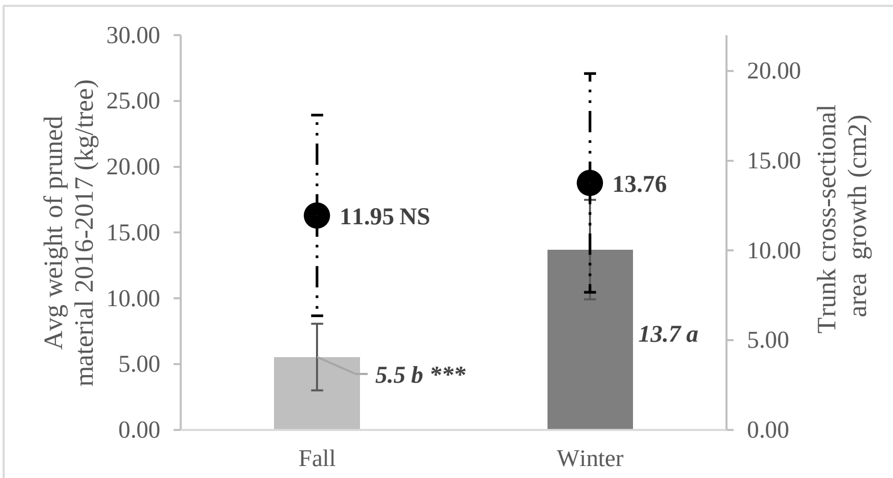

*Figure 1: Comparison between weight of wood (and leaves only in fall) removed per tree (kg) in 2016-2017and trunk growth (2016- 2017) for each pruning treatment (secondary axis, black dots). Significance: * p<0.05, ** p<0.01, ***p<0.001, ns= not significant for Type III sums of squares model significance; Student-Newman-Keuls post-hoc test to assign letter groups to arithmetic means where model was significant. Error bars are ±SD.*

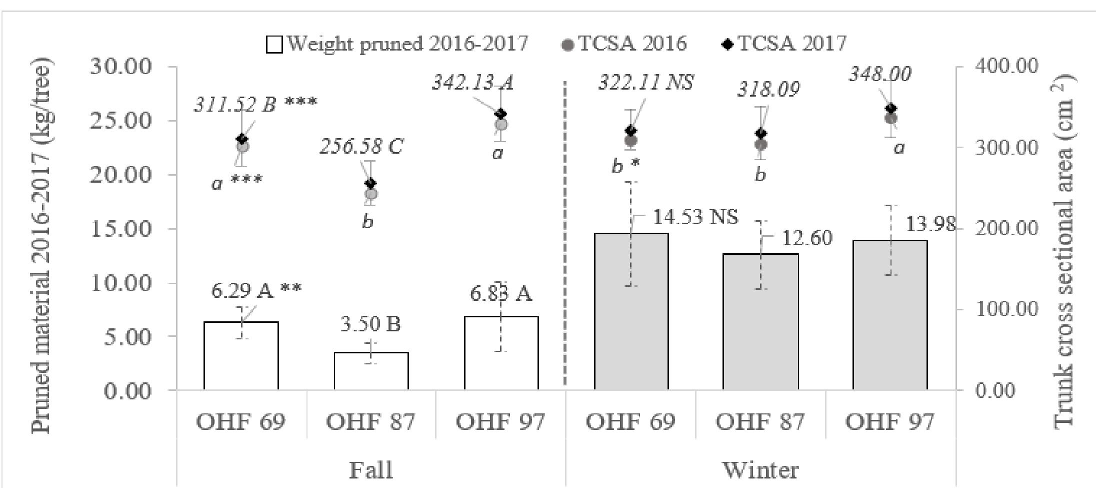

*Figure 2: Comparison between weight of wood (and leaves, fall only) removed per tree (kg) and trunk cross sectional area (TCSA cm^2) in 2016-2017 for each rootstock by pruning treatment. Significance: * p<0.05, ** p<0.01, ***p<0.001, ns= not significant for Type III sums of squares model significance; Student-Newman-Keuls post-hoc test to assign letter groups to arithmetic means where model was significant. Error bars are ±SD.*

Trunks of winter pruned trees were significantly larger than fall pruned trees for all rootstocks and, regardless of pruning time, OHF97 trunks were the largest and OHF87 were the smallest. Fall pruning-OHF87 was significantly lower than all of the other combinations, while no difference between the three rootstock in the winter pruning for TCSA 2017 (Fig. 2).

Figure 3 describes all the pruning treatments performed in this trial from 2014 to 2017 reported as production years 1 to 4.

Pruning treatment and rootstock did not have a significant impact on average flower bud counts per m^3. In 2016, fall pruned trees reported 25 flower buds/m^3 while winter pruned had 21 flower buds/m^3, the resulting difference was not statistically significant. No difference between pruning treatments was reported for 2017 either. A generally lower amount of buds were counted in 2017 compared to 2016 (range 8.5-10.5 buds/m^3). Also in 2016, we noticed a general reduction in flower buds/m^3 in comparison to 2015, when they were 32 and 25 buds/m^3 for Fall+summer and winter pruned trees, respectively (difference not significant in 2015 as well). Also in the interaction means (pruning time x rootstock), there was no significant difference in number of flower buds/ m^3 in 2016 and 2017 (data not shown).

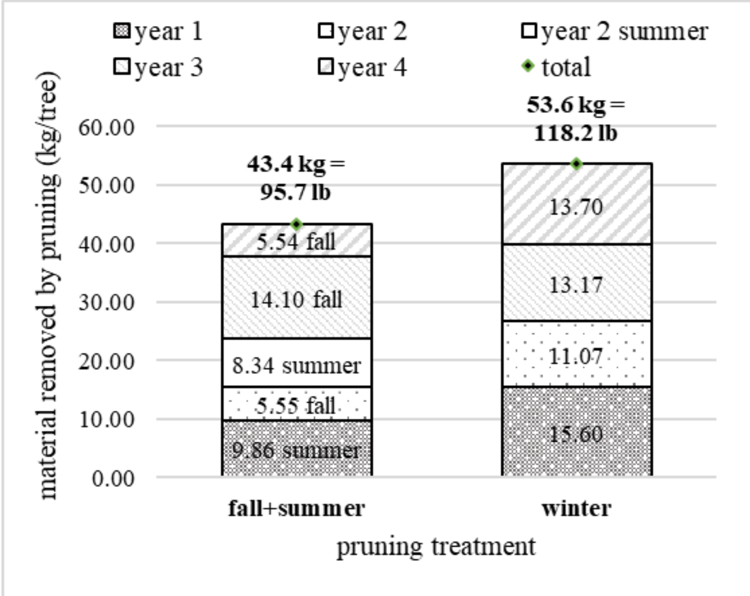

Figure 3: Pruning history of the experiment in 4 years by pruning treatments.

The fruit set (percentage of total flowers that set to fruit) per branch count showed no differences between pruning time, while significant differences were found between rootstocks in 2016. OHF87 had the highest percentage of fruit set per branch and OHF69 had the lowest when considering both pruning treatments ($p<0.05$). This difference is due to the behavior of the rootstocks in the winter treatment because there was no significant difference in fall (Fig. 4). OHF87 winter pruned trees had 1.8 times higher percentage of fruit set than OHF69 (Fig. 4).

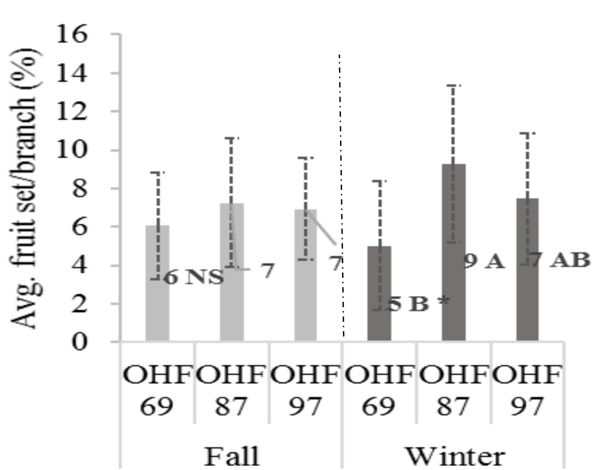

*Figure 4: Comparison between fruit set (%) on a branch for each rootstock by pruning treatment in 2016. Significance: * p<0.05, ** p<0.01, ***p<0.001, ns= not significant for Type III sums of squares model significance; Student-Newman-Keuls post-hoc test to assign letter groups to arithmetic means where model was significant. Error bars are ±SD.*

Yield 2016 and 2017

The pre-harvest fruit ripening assessment by DA meter (I_{AD}=index of absorbance difference, indirect estimation of fruit ripening) in 2016 on OHF87 rootstock and both pruning treatments one week before harvest revealed that the majority of fruit (approx. 39%) was classified as $2.00<I_{AD}<2.09$ for both treatments, while fall pruned trees seemed to have riper fruit in $1.90< I_{AD}<1.99$ than fruit on winter-pruned trees. This behavior is opposite to that observed in the previous two years (Fig. 5A). In 2017, knowing it was a late season, the pre-harvest assessment was done on August 28th and it revealed a general delay in maturity approx. 46% of the fruit were classified as $2.00<I_{AD}<2.09$ for both treatments (Fig. 5B). The harvest in 2017 was done two weeks later than the assessment.

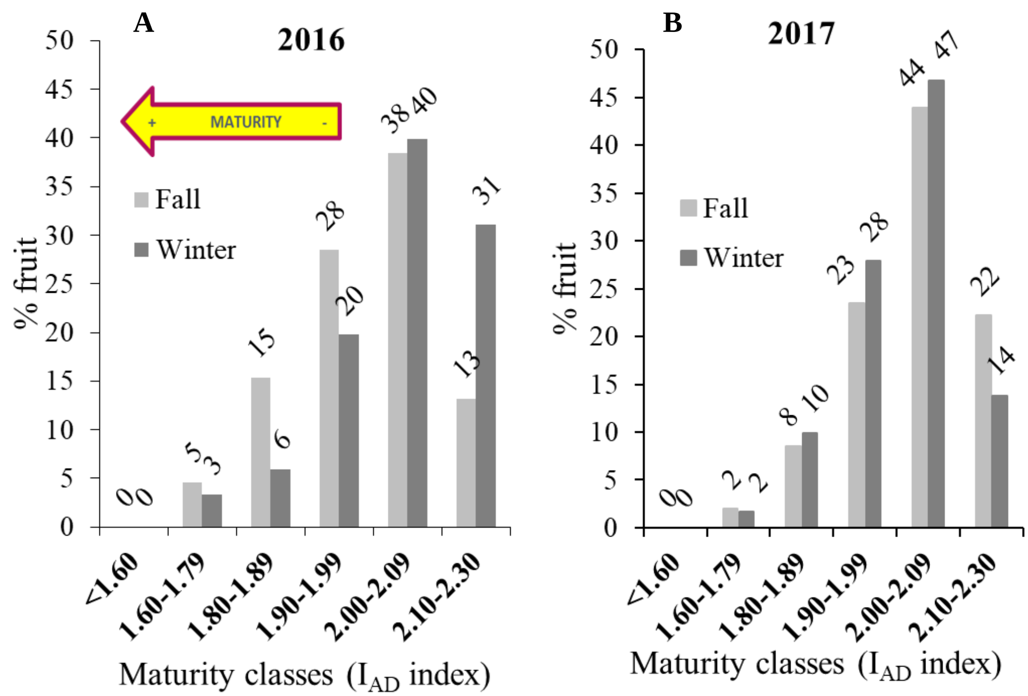

Figure 5: Fruit distribution in I_{AD} classes (indirect maturity assessment) one-two week before harvest in fall and winter pruned trees in 2016 (A) and 2017 (B).

Yield in 2016 had significantly more and heavier fruit from trees pruned in the winter than those in the fall (Table 1). The difference between treatments was around 35 lb/tree or 71 fruit/tree (Table 1). The average fruit weight for winter pruned trees was 7 g higher than fall pruned trees and they were commercially sized between 90-100 fruit/box and 100-110 fruit/box, respectively (Fig. 5A). Winter pruned trees had significantly higher yield efficiencies, crop loads, but more fruit with sunburn and cork than trees pruned in the fall, as in 2015. No frost damage was detected in 2016. There was no significant difference between the three rootstocks for productivity, average fruit weight, and incidence of sunburn and cork. However, OHF97 had significantly lower yield efficiencies and crop loads than the less vigorous rootstocks (Table 1).

In contrast to 2016, the 2017 Fall treatment produced significantly more fruit with a higher yield/tree and higher yield efficiency and crop load than winter pruned trees (Table 2). The difference between treatments averaged 16 lb/tree or 42 fruit/tree (Table 2). The average fruit weight for winter pruned trees was only 6 g higher than fall-pruned trees. Pears harvested in 2017 were commercially sized between 80-90 fruit/box (Fig. 6B). No frost damage was detected in 2017. Cork and sunburn were neglible in 2017, and no significant treatment differences occurred (Table 2). Among the three rootstocks, OHF87 produced more fruit with a higher yield/tree, yield efficiency and crop load than the others, although average fruit weight did not differ, ranging between 209 and 217 g (Table 2). Sunburn and cork incidences did not show any significant differences between rootstocks. From significance in the interaction between pruning treatment and rootstock we noticed that all the significance between rootstock was only confirmed within the fall pruning, while the three rootstocks performed the same if pruned with winter pruning. This lack of significance between means in pruning could also suggest a higher variability of those trees that hid differences between rootstocks.

Table 1: Anjou yield and disorders in Cashmere, WA in August 2016.

Treatment	Count fruit /tree		Net yield (lb /tree)		Fruit weight (g)		Yield efficiency (lb /TCSA)		Crop load (num. fruit /TCSA)		Sunburned fruit (%)		Fruit with cork (%)	
Pruning season														
Fall	251	**B**	108.8	**B**	198	**B**	0.38	**B**	0.88	**B**	0.74	**B**	0.08	**B**
Winter	322	**A**	143.6	**A**	205	**A**	0.46	**A**	1.04	**A**	1.77	**A**	0.20	**A**
Significance	***		***		*		**		*		***		*	
Rootstock														
OHF69	295		131.1		205		0.43	**A**	0.98	**AB**	0.87		0.16	
OHF87	294		129.5		201		0.47	**A**	1.08	**A**	1.62		0.03	
OHF97	269		118.1		199		0.36	**B**	0.82	**B**	1.22		0.24	
Significance	NS		**NS**		**NS**		**		*		NS		NS	
Signif. Prun.XRoot.	**NS**		**NS**		**NS**		**NS**		**NS**		**NS**		**NS**	

*p<0.05, *; p<0.01, **; p<0.001, ***; NS, not significant for Type III sums of squares model significance. Student-Newman-Keuls post-hoc test to assign letter groups to arithmetic means where model was significant.*

Table 2: Anjou yield and disorders in Cashmere, WA in September 2017.

treatment - 2017	Count fruit/tree		Net yield (lb)		Fruit weight (g)		Yield efficiency (lb/cm^2 TCSA)		Crop load (num. fruit/TCSA)		Sunburned fruit (%)	Fruit with cork (%)
Pruning season												
Fall	322	**A**	149	**A**	211	**B**	0.51	**A**	1.12	**A**	0.01	0.90
Winter	280	**B**	133	**B**	217	**A**	0.41	**B**	0.87	**B**	0.01	1.27
Significance	**		*		*		**		**		**NS**	**NS**
Rootstock												
OHF 69	282	**B**	133	**B**	216.04		0.43	**B**	0.90	**B**	0.00	1.39
OHF 87	344	**A**	157	**A**	209.14		0.57	**A**	1.25	**A**	0.03	0.75
OHF 97	278	**B**	133	**B**	216.82		0.39	**B**	0.82	**B**	0.00	1.11
Significance	**		**		**NS**		***		***		**NS**	**NS**
Sign. pruning x root.	*		**		**NS**		***		***		**NS**	**NS**

*p<0.05= *, p<0.01=**, p<0.001= ***, NS = not significant for Type III sums of squares model significance. Student-Newman-Keuls post-hoc test to assign letter groups to arithmetc means where model was significant.*

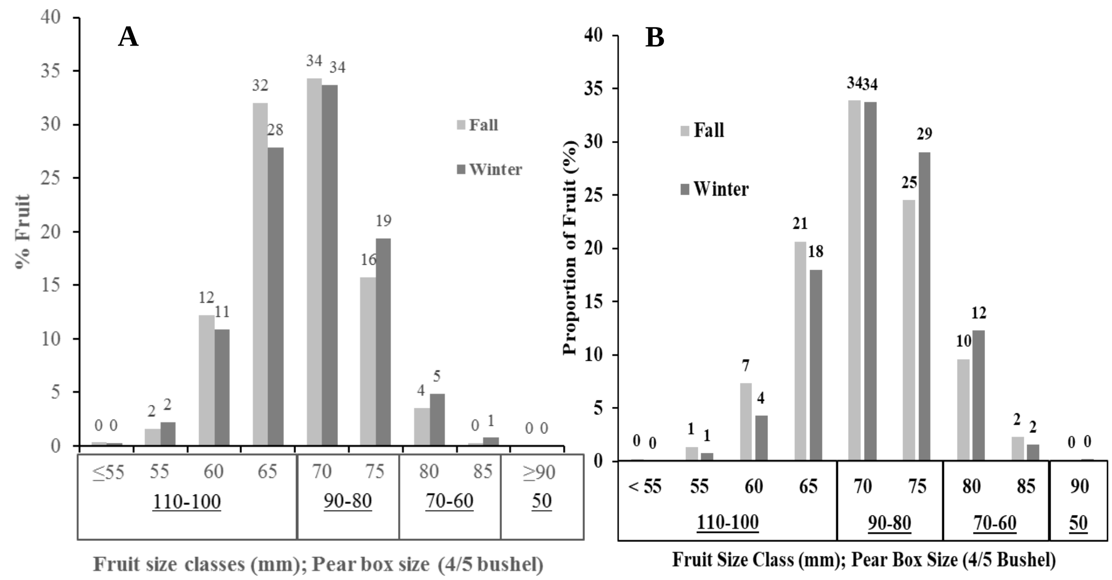

Figure 6: Fruit size distribution (in mm diameter) for fall and winter pruning at harvest 2016 (A) and 2017 (B). Correspondence in 4/5 bushel pear box underlined below diameters in mm.

Fruit quality (harvest 2015)

Fruit from 2015 harvest on OHF87 rootstock had differences in post-storage quality between pruning treatments. After 5 months, fruits from the winter pruning treatment ripened significantly faster (according to the I_{AD} drop) and had a lower firmness than fall+summer pruned trees (Table 3). Winter fruits also lost significantly more weight and ripened faster after 7 days of ripening than fall+summer fruits after 7 months of storage. At harvest, fruits from both treatments were similar in hue (color) and chroma (shade), but fall+summer pruned fruit were significantly greener color after 7 months of storage than winter fruit (Table 3). At harvest fruits from both treatments were similar in firmness, but fall+summer fruits were significantly firmer after 5 months of storage than the winter fruit and the trend continued (although not significant) in the 7th month pullout. At harvest, fall+summer pruned trees had significantly more soluble solid content (SSC) than winter, but after storage there was no significant difference among the treatments (data not shown). At harvest and after 5 months, fall+summer fruits showed lower titratable acid (TA, $p<0.05$) than winter fruits and after 5 months, higher pH than winter fruit. Incidence of cork was similar at harvest among the pruning treatments, but winter fruit had more cork after 5 and 7 months of storage than fall+summer fruit. The I_{AD} ripening classes were distinguished at harvest and the ripest class in both treatments ripened the most and was the most yellow after 5 and 7 months in storage. The opposite was observed for the most unripe class. At 5 months for both treatments, the ripest class (Z) was the least firm, had the highest SSC, and winter only had the highest percentage of dry matter. At 7 months considering both treatments, the second and third ripest classes (B, C) was least firm and classes A and B had the highest dry matter %.

Samples of pear flesh tissue from T1 and T2 (harvest 2015) were analyzed for calcium, nitrogen, and other macro and micronutrients and there were no significant differences between winter and fall+summer pruned fruit except for a higher percentage of potassium (K%) in winter fruit than fall (data not shown).

Table 3: Fruit quality parameters (Anjou/OHF87 fruit harvested in 2015 and stored up to 7 months) T1 =5 months of storage, and T2= 7 months of storage on quality.

Storage 2015	Treatment	Weight drop (g) after storage	Weight drop (g) after 7 days of ripening + storage	IAD index drop after storage	IAD index drop after 7 days of ripening + storage	Color parameter: hue	Color parameter: chroma	Firmness (lb) avr of 2 faces	SSC (Brix)	pH	Titr. Acidity (% malic ac.)
5 months (T1)	Fall +sum pr.	5.7	7.2	0.28 B	0.19	108.5	41.9 B	7.82 A	14.2	3.89 A	0.26
	Winter pr.	5.9	7.5	0.32 A	0.21	107.6	42.8 A	6.49 B	14.3	3.73 B	0.27
	Significance	NS	NS (5.3)	**	NS	NS	***	***	NS	***	NS
7 month (T2)	Fall +sum pr.	7.0 B	8.4 B	0.47 B	0.41 B	105.8 A	42.6	4.27	14.4	3.66	0.20
	Winter pr.	8.0 A	9.0 A	0.52 A	0.46 A	104.2 B	42.2	3.79	14.1	3.68	0.22
	Significance	***	**	*	**	***	NS (5.2)	NS (5.2)	NS	NS	NS

*Pr = pruning   p<0.05, *; p<0.01, **; p<0.001, ***; ns, not significant for Type III sums of squares model significance*
Student-Newman-Keuls post hoc test to assign letter groups to arithmetic means where model was significant.

Psylla and Mite Densities

Overwintering psylla adult densities were high in 2016 before insecticide applications were made; however, they were low throughout the rest of the season. No pre-treatment counts were made in 2017, but post-treatment adult counts indicated low densities throughout the season until September, when populations began to rise again.

Leaf counts of insect densities (psylla and mites) indicated low populations in 2016 and 2017, with no significant treatment, rootstock, or interaction differences among means. The only exception was the psylla nymphs in 2017, which peaked in mid-July. Overall, densities of psylla nymphs was not different between pruning treatments (Fig. 7).

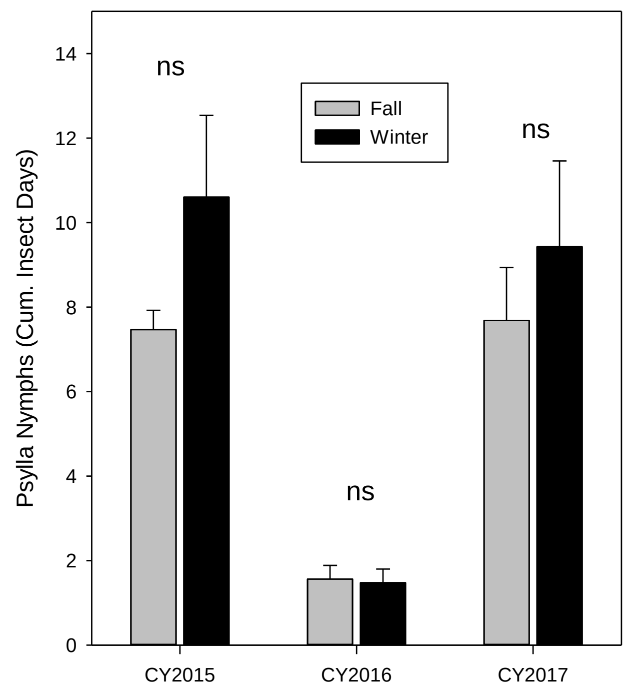

Fig. 7. Seasonal cumulative insect days for psylla nymphs, 2015-2017 (mixed model ANOVA with Tukey mean separation, P<0.05).

Fruit damage from psylla was moderate in 2015 and 2016; however, in a very high pressure year, 2017, it increased ca. 40% in the highest treatment (winter-pruned), which was significantly higher than the fall+summer pruned treatments (Fig. 8). This is the first indication in this experiment that the fall+summer pruning regime, presumably with lower vigor, may have promoted lower psylla populations. While some (non-significant) variations occurred in lepidopteran damage (codling moth and surface feeding), these are difficult to attribute to the pruning regime, except perhaps through improved coverage in the fall+summer where greater light penetration may correlate with greater spray penetration.

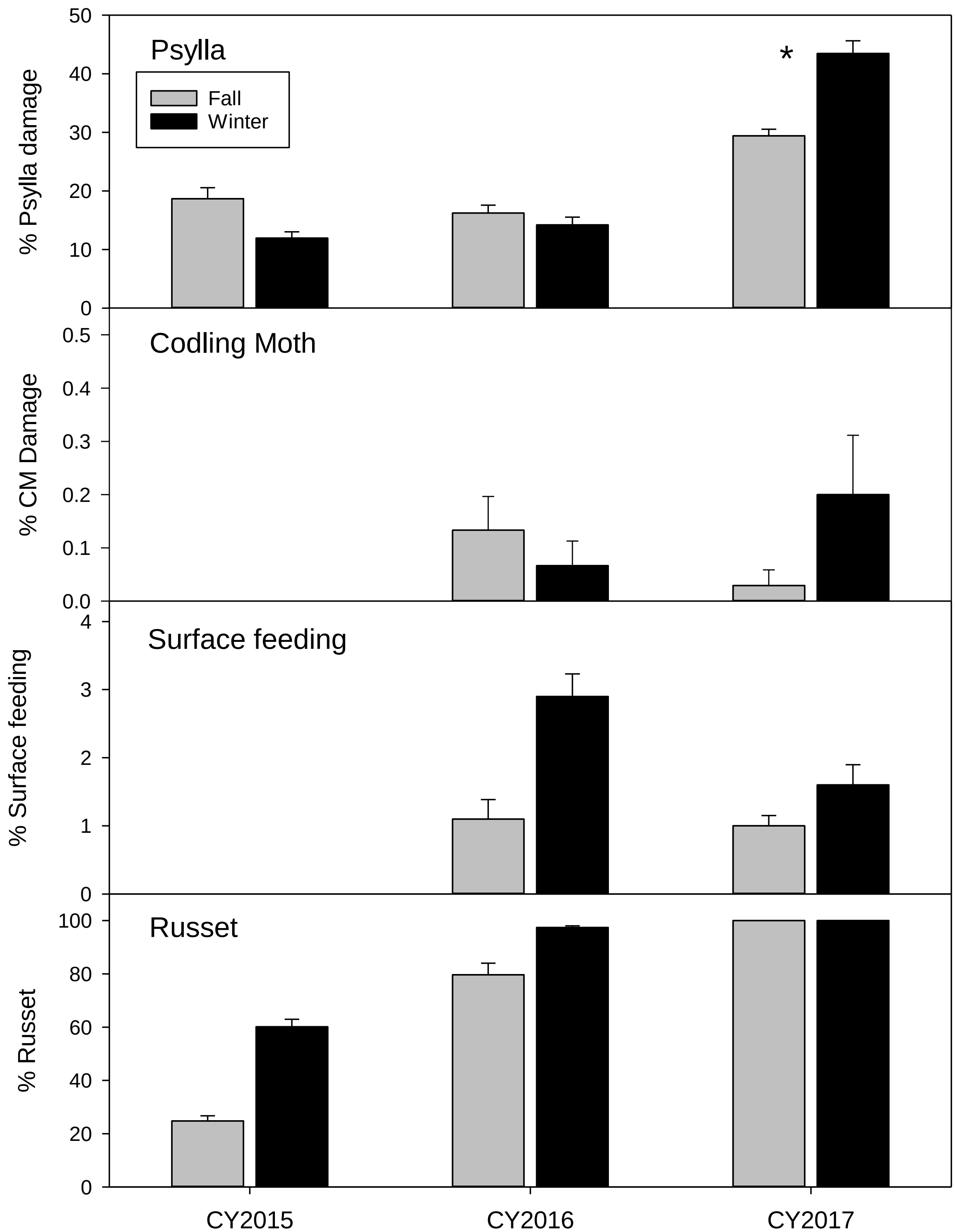

Fig. 8. Fruit damage from pear pests in two pruning timing treatments, 2015-2017. Differences between means indicated by an asterisk (*)(mixed model ANOVA with Tukey mean separation, P<0.05).

EXECUTIVE SUMMARY

Controlling vigor in Anjou pear trees is still an ongoing challenge in Washington pear orchards. The tree vigor depends on many factors like cultivar, rootstock, nitrogen fertilization, and pruning/training systems. The cultivar ‘Anjou’ is inherently more vigorous than other cultivars, notably ‘Bartlett’, which produces a smaller, more manageable tree. Dwarfing rootstocks, largely adopted in the apple industry are not utilized in pear orchards. The only available dwarfing rootstock for pear are quince genotypes, but they are seldom planted due to the poor winter hardiness and compatibility issues. Vigor is also the main driver of higher pear psylla populations, one of the key pests of pear. This phloem-feeding pest thrives on high nitrogen levels, driving up its reproductive capacity. In some regions of the state, this pest threatens crop yield and quality annually, despite intensive pesticide control programs. The presence of honeydew at harvest also discourages pickers from working in pear orchards.

In this project we aimed to achieve the best possible horticultural and entomological outcomes to control vigor, limit psylla and maintain fruit quality.

The trial was carried out in an ‘Anjou’ orchard planted in 1998 (Cashmere, WA) on three different rootstocks: Old Home x Farmingdale OHxF97, OHxF69 and OHxF87. OHxF97 is considered a vigorous rootstock in comparison with the other two (semi-vigorous). Specifically, we proposed to alter pruning management (fall and summer pruning versus the current standard winter pruning) to reduce tree vigor while maintaining yield and quality (including cork spot). After 4 years, trees pruned with fall (+summer) technique showed a better light penetration and a more homogeneous fruit bud distribution in the canopy that reflected in a higher yield per tree and yield efficiency with fruit just slightly smaller than winter pruning, but no significant difference in the main quality traits. In the fourth year only, fruit damage by pear psylla was lower in the fall (+summer) pruned trees, an indication of vigor reduction by this pruning regime.

Project outcomes:

- **Field days**
  Anjou and Bartlett pruning, January 10, 2017 Tonasket (S. Musacchi)
  The young growers pruning tour, March 3, 2016 Cashmere/Monitor (S. Musacchi)
- **Video**
  2017 https://www.youtube.com/watch?v=Iykwa4VxFrA&t=14s. How to use the Click Pruning Method with Stefano Musacchi - Hort Show, 2016. Published on Jan. 23, 2017 (2,180 views).
  2015 https://www.youtube.com/watch?v=5h5aQ5DwYOo. Pruning Bartlett Pear to Optimize Fruit Quality. Published on Feb. 17, 2015. (44,408 views).
- **Web articles**
  http://www.goodfruit.com/understanding-the-click-pruning-technique-video/
  http://www.goodfruit.com/dynamic-pruning-keeps-trees-productive/
  https://www.youtube.com/watch?v=5h5aQ5DwYOo
- **Professional presentations/conferences**
  Musacchi S., Serra S. and Mattheis J. “Fall and summer pruning to control vigor in d’Anjou pear” (oral presentation by Musacchi S.). XI International Symposium on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems, Bologna, Italy (August 2016).

Future direction:

- how pruning impacts dry matter accumulation in pear fruit
- moving toward a high density-fruit wall-machine friendly pear orchard on dwarfing rootstocks.