Project Title: Further analysis of WA Codling Moth Management Practices Grower Survey

Key Words: codling moth, apple, pear, task force, survey

Report Type: Final Project Report

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Funding Duration:
Amount:
Agency Name:
Notes:

Item			2022
Salaries			$8,000.00
Benefits			
Wages			
Benefits			
RCA Room Rental			
Shipping			
Supplies			
Travel			
Plot Fees			
Miscellaneous			
Total	$0.00	$0.00	$8,000.00

Footnotes: Salary covers sub-contractor fees for stats analysis

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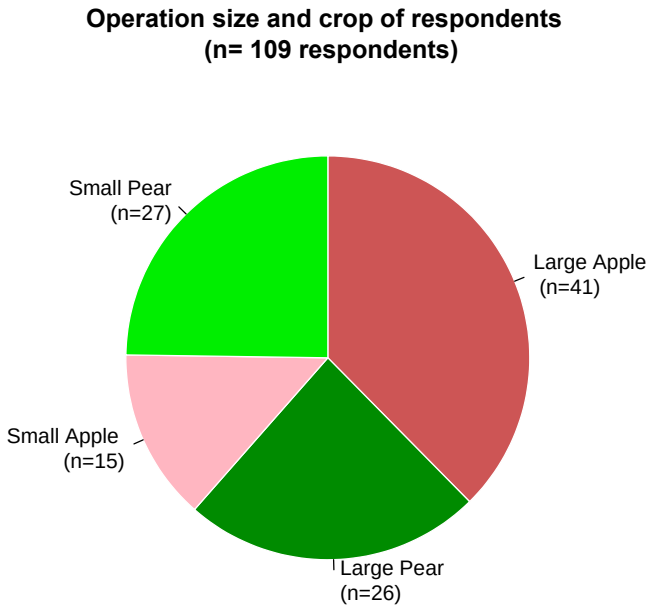
Introduction:
In response to industry concerns regarding a perceived loss of control of Codling Moth (*Cydia pomonella*, hereafter "CM") in apple and pear crops in the Pacific Northwest, the Washington Tree Fruit Research Commission formed the Codling Moth task force in September of 2020. The task force was comprised of growers, industry leaders, and university researchers. The goal of the task force was to 1) better understand what orchard management and CM control tactics are currently being used, and 2) to use a survey data to better understand if there are common practices working/not working. To do this, the committee created and deployed an industry-wide survey. The survey was sent out to apple and pear orchard owner/managers and pest management consultants in Washington. In total, 127 respondents completed enough of the survey to analyze. For each portion of this report, the number of respondents who answered that specific question (which differs from the overall number of respondents of the survey) will be included (notated throughout this report as "n=…").

Structure of this report: Chris Adams, head of the Codling Moth Task Force, narrowed down the survey questions to be analyzed to a series of "Key Questions" from the full survey and requested that for each Key Question a separate report section be given for "apple" and "pear" growers. Furthermore, Chris requested that for both apples and pears, differences between "Small" growers (which we defined as <100 acres) and "Large" Growers (defined as >100 acres) as well as the impact of organic management practices. For each Key Question, we used the most relevant and useful data available to glean some insights into how management differs based on:
-apple and pear growers
-large and small operations
-organic management

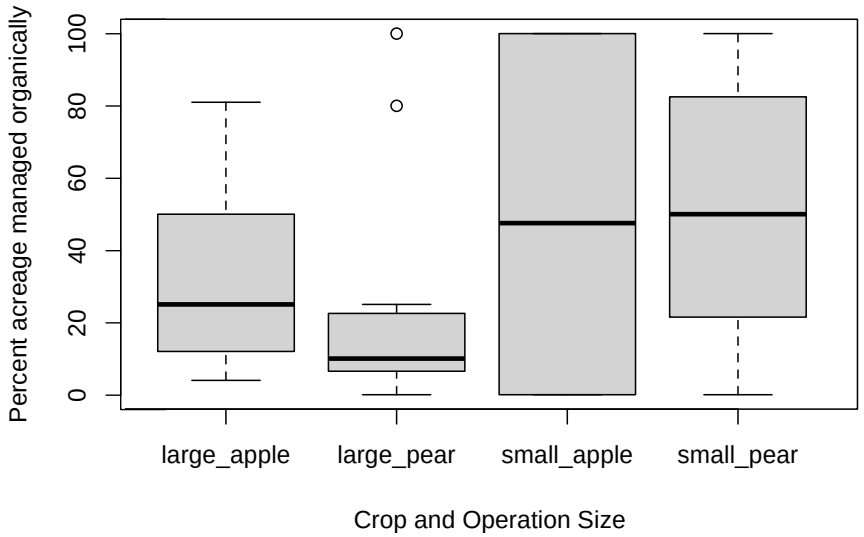
It should be noted, that by parsing out this relatively small dataset in so many ways, this often resulted in comparisons of very low sample sizes. In the chi-square analyses, we were able to avoid the normal approximation, and run the analyses on very low sample sizes, but this should be taken into account when drawing conclusions. Significant differences (or not) are noted with associated p-values (indicated p= 0.0…). For other analyses, specifically regarding comparisons of conventional vs organic management practices, there were simply far too few (sometime only 1-3 responses), which were unable to be analyzed in the ways anticipated. For these examples, graphs were created to visually inspect the differences between treatments. Sample size is noted in the figure title throughout the report. Throughout this report, for each question, the specific test used, or the reason for not using a test are noted.

Who took the Survey?
Of the 182 respondents who logged in to take the survey, 135 completed enough of the survey to use (>8% of the survey, i.e., more than just their name). Of the 112 respondents who reported their role, 74 (66.1%) identified as "manager/owner", and 38 (33.9%) identified as "consultant." Respondents were asked to take the survey for a specific crop, either apples OR pears, not both. Of those 113 who reported their cropping system, 60 (53.1%) responded for "apples", and 53 (46.9%) responded for "pears." Because of the variability in the size (acres) of operations and the potential for management to differ between larger and smaller operations, The committee head requested we group the data into 2 groups: large (>100 acres) and small (<100 acres). For those respondents who reported both cropping system and acreage, here is the breakdown:
Figure 1.



Additionally, the survey asked respondents "What type of orchard management do you perform?" with the ability to fill in acreage percentages managed "conventionally", "organically", or in "transition". Growers were not able to self-identify as "conventional" or "organic" (many manage in both ways) but many did report what percentages of the acreage they farmed for each management type. For some questions, we created and used a continuous "% acreage managed organically" variable from the data available. To answer other questions, we binned growers based on their predominant management acreage (e.g., "mostly conventional" = >75% acreage managed conventionally, "mostly organic" = >75% acreage managed organically). Lastly, for a few other questions, there was survey data specific to "conventional", "organic", or in "transition". For each question, we chose the most relevant approach to tease out any differences that might be important based on farm management preference. This breakdown of how respondents' reported % acreage managed organically is shown in figure 2.

Figure 2.*



*For those unfamiliar with this type of graph, it's called a "box plot" or "box and whisker plot." The thick black bars indicate the middle (median) of the dataset, the grey boxes indicate the middle quartiles of the data (where 50% of the data are), and the 'whiskers' indicate the upper and lower quartiles (where the upper 25%, and lower 25%, respectively) of the data lie. The rouge datapoints indicated are considered outliers.

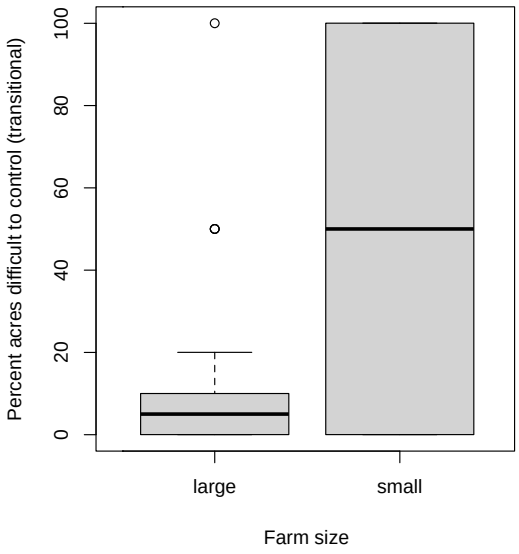
KEY QUESTIONS:

Question 5, part 1: **"What percentage of acreage is codling moth difficult to control (for each type of management)?"** To address this question, we used a chi-square test to look at differences between small and large growers on land on organic, transitional, and conventional acreage.

Apple Growers' response

Small vs. Large Operations: On both organic and conventional orchards, there was no difference in the percentage of acreage on which CM was difficult to control between small and large orchards ($p= 0.4898$ and $p= 0.08296$, respectively). On transitional orchards, small orchards reported a significantly higher % of acreage on which CM was difficult to control ($p= 0.04198$) shown in figure 3.

Figure 3.



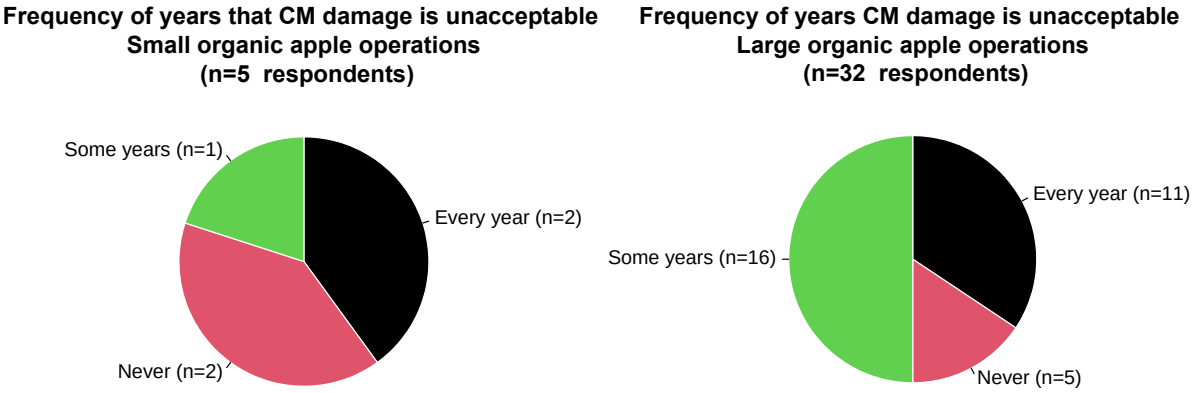
Pear Growers' response:
Small vs. Large Operations: On organic, transitional, and conventional orchards, there was no difference in the percentage of acreage on which CM was difficult to control between small and large orchards (p= 0.1724, p= 0.6037, and p= 0.8836, respectively)

Question 5, Part 1 Summary: Generally, for both apples and pears there were no major differences in the percentage of acreage on which CM was difficult to control. The exception to this was on transitioning apple acreage, where small farms reported a higher percentage of acreage that was difficult to control.

Question 5 - part 2: "What Frequency of years is CM damage unacceptable?" To address this question, we used a chi-square test to look at differences between small and large growers on land under organic, transitional, and conventional orchards.

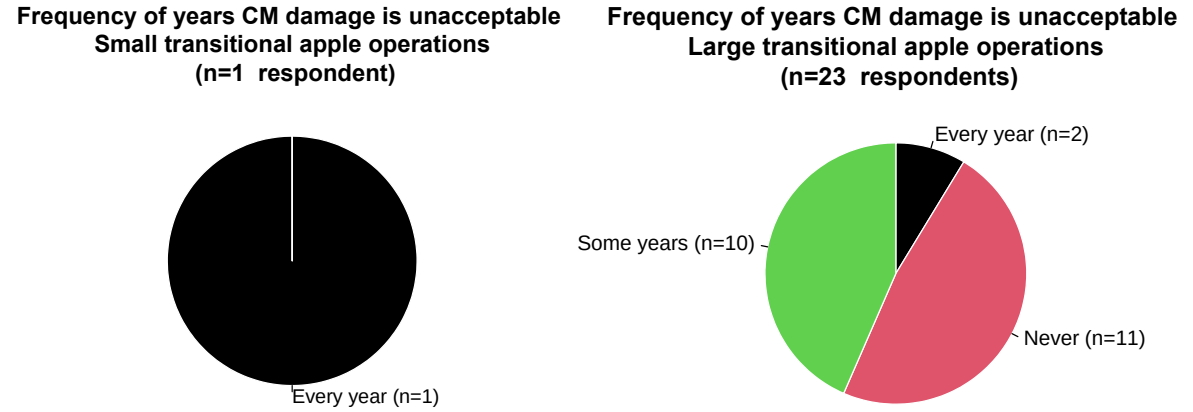
Apple Growers' response:
Small vs. Large Operations: On organic acreage, there was a significant difference in the frequency of years CM damage was found to be unacceptable between small and large orchards (p= 0.0035 *but note small sample size, particularly of small orchards). Larger farms reported a higher percentage of damage in "some years" where smaller farms reported a higher percentage of "never." These differences are shown in Figure 4.

Figure 4.



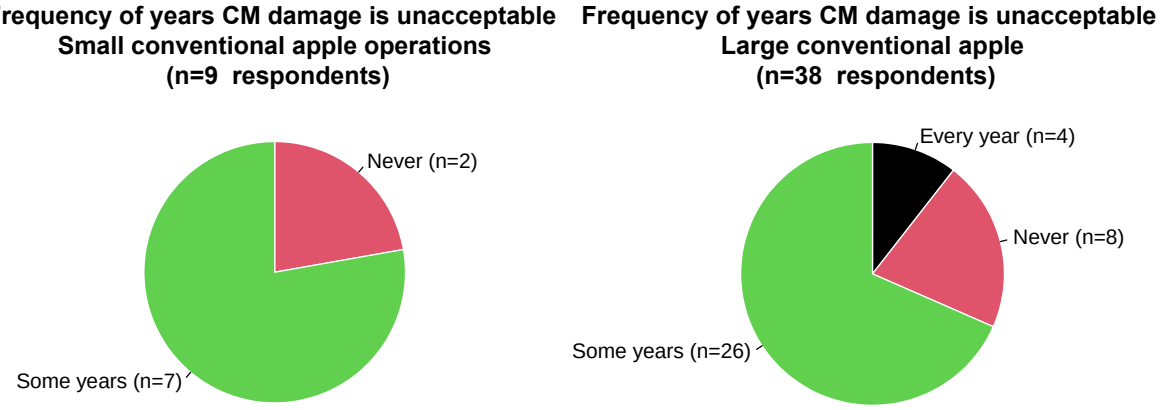
On transitional acreage, there was a significant difference in the frequency of years CM was found to be unacceptable between small and large orchards (p= 0.02949, *but note VERY small sample size, particularly of small orchards). These differences are shown in figure 5.

Figure 5.



On Conventional acreage, there was a significant difference in the frequency of years CM was found to be unacceptable between small and large orchards (p=0.0005). Some percentage of large orchards reported unacceptable damage every year. These differences are seen in figure 6.

Figure 6.



Pear Growers' response*:*

Small vs. Large Operations: On organic, transitional, and conventional acreage, there was no difference found in the frequency of years CM was found to be unacceptable between small and large orchards (p= 0.07346, p= 0.2359, and p= 0.1639, respectively).

Question 5, Part 2 Summary:

Although the response rate for small orchards in all three systems is very low for this question, and there is variability across the 3 systems, it is interesting to note that there is consistently unacceptable damage some years. No interesting differences emerged from the pear growers.

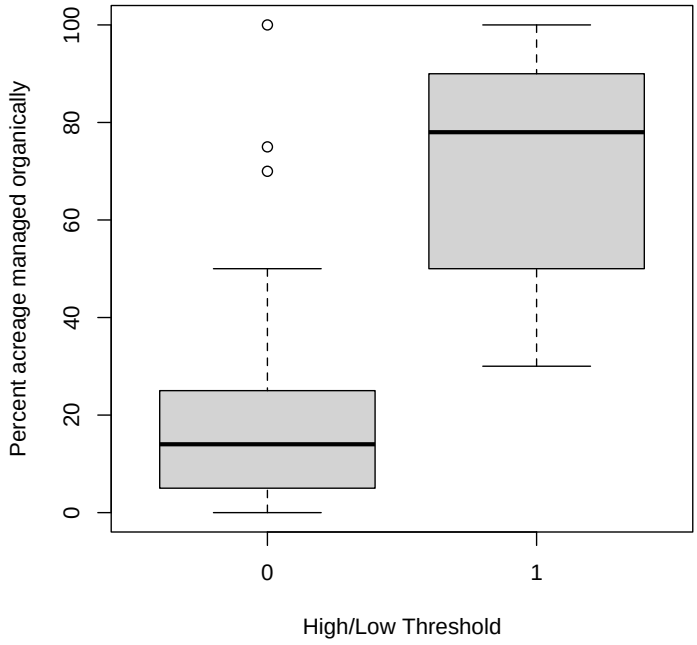
Survey Question 6: "What is your threshold for codling moth damage?" We analyzed data for those who reported a % damage, which excluded some responses. Many folks did not answer this question, many did not provide a percentage, but instead stated a number of stings/trap. Others stated differences between Taiwan market and other markets. I was directed to this approach by the head of the task force. To compare large and small farms we used a chi-square analysis. To compare differences in thresholds based on organic management we took a different approach. In communicating with Tobin Northfield regarding this question, we decided, based on the distribution of the data, to divide the data into 2 groups (<5% damage and >=5% damage) and run a logistic regression.

Apple Growers' response:

Small vs. Large Operations: There was no significant difference in CM thresholds between small and large farms (p= 0.8576).

Organic Management: There was, however, a difference in CM thresholds based on the % acreage managed organically (p= 0.01695); growers with a higher percentage of land managed organically had a higher threshold for damage than those with less land managed organically. This difference is indicated in figure 7.

Figure 7.



Pear Growers' response:
Small vs. Large Operations: There was no significant difference in CM thresholds between small and large farms (p= 0.8266).

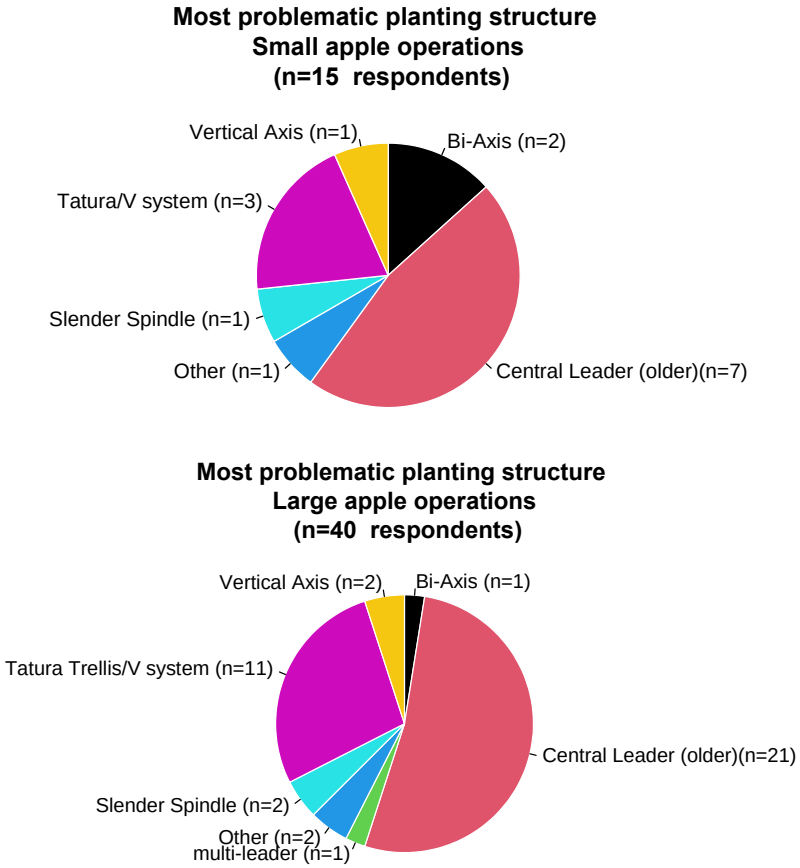
Organic Management: There was no difference in the CM damage threshold based on % organically managed acreage (p= 0.913).

Question 6 Summary:
In both apples and pears, the size of the operation did not seem to matter with regards to a CM damage threshold. However, with apples, the more organic acreage a respondent reported, the high CM damage threshold they had.

Question 7: "In your highest-pressure block, what is your tree planting?" It should be noted that many people answered "other", then wrote in "multi-leader". In fact, multi-leader was the only "other" option described. "Other" was replaced with "multileader" where applicable. The small vs. large farm comparison data were analyzed with a chi-square test. For the organic comparison, it doesn't really make sense to ask how the type of tree that is most problematic, changes as a continuous increase in % acreage managed organically, however, we did look at how this changed with subsets of the data that were "mostly organic" (>75% organic) or "mostly conventional" (>75 conventional).

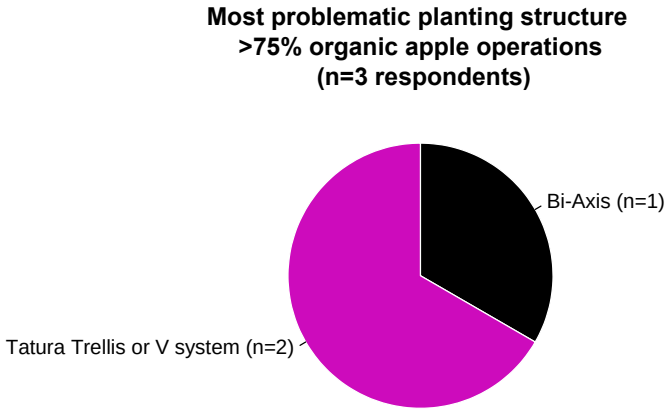
Apple Growers' response:
Small vs. Large Operations: There was a significant difference in the most problematic tree type found between small and large growers (p=0.0001) with small operations reporting a higher amount of bi-axis and larger operations reporting a small percentage of "multi-leader" as the most problematic tree structure. These differences are shown in figure 8.

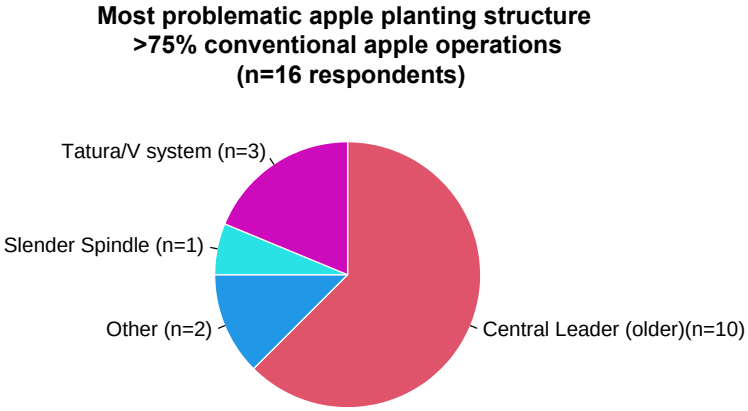
Figure 8.



Organic Management: Visual exploration of how mostly organic and mostly conventional operations report problematic tree structure (*note small sample sizes). These comparisons are found in figure 9.

Figure 9.



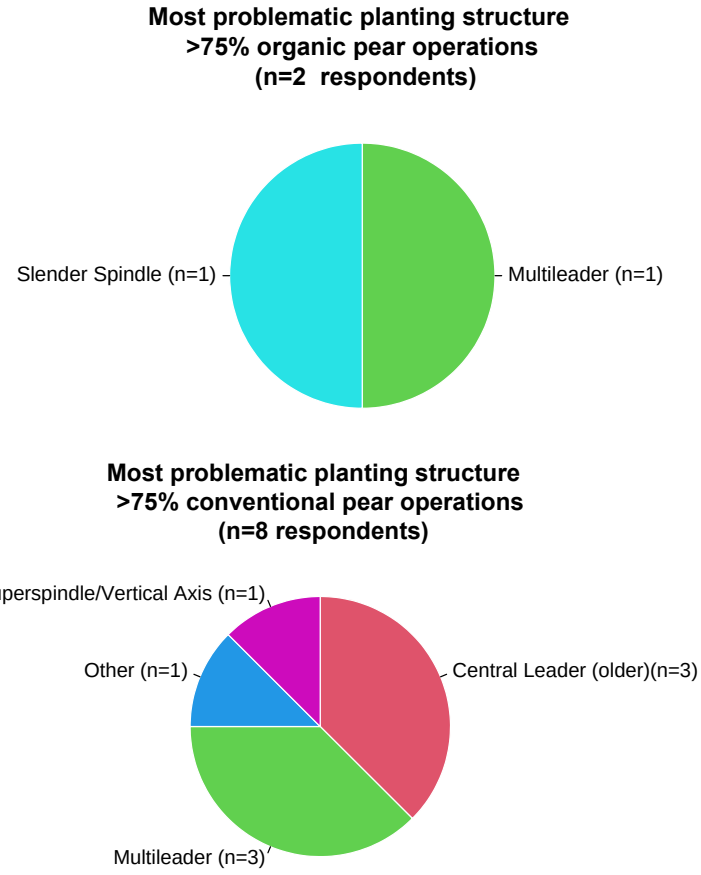


Pear Growers' response:

Small vs. Large Operations: There was no difference in the most problematic tree structure between small and large orchards (p= 0.5897, note, central leader dominant in both).

Organic Management: Visual exploration of how "mostly organic" (>75% organic acreage) or "mostly conventional" (>75% conventional acreage) operations report problematic tree structure (*note small sample sizes). These comparisons are shown in figure 10.

Figure 10.



Question 7 Summary

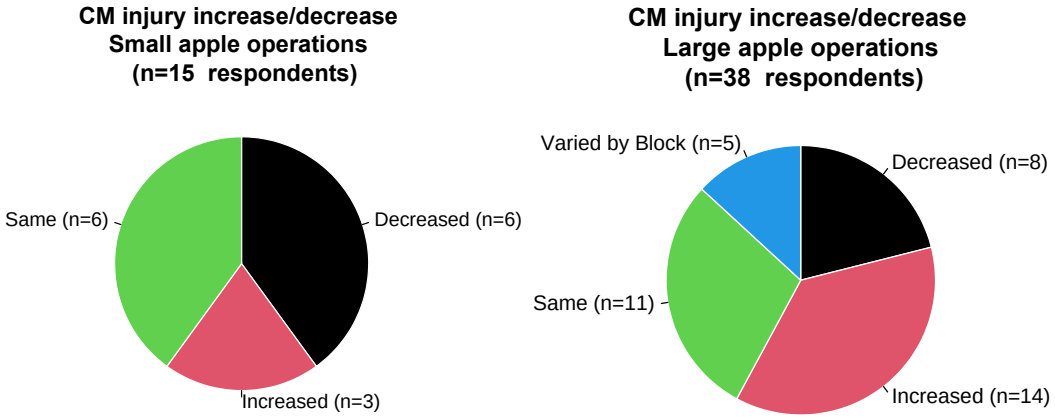
While there is some variability in reporting, both in terms of response rate, as well as tree structures reported, older central leader trees dominated as the most problematic tree structure.

Survey Question 8 "Over the past three years, codling moth injury in the orchard(s) you own or manage has" (select choice – Increased/decreased/remained the same). The small vs. large farm comparison data were analyzed with a chi-square test. For the organic management comparison, we visually explore the differences in changing CM injury for subsets of the data that were "mostly organic" (>75% organic) or "mostly conventional" (>75 conventional).

Apple Growers' response:

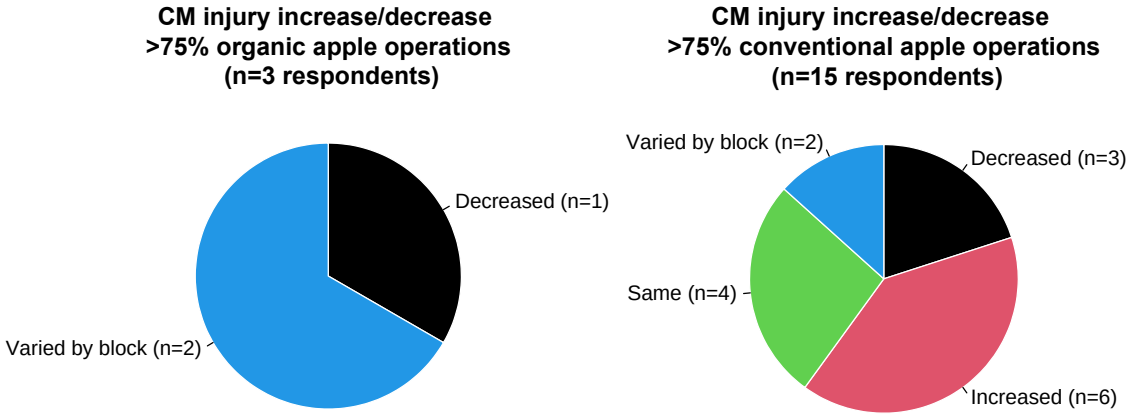
Small vs. Large Operations: There was a difference in whether CM injury increased, decreased, or remained the same on small vs large operations (p=0.0005), with small operations seeing larger percentages of injury staying the same or decreasing, and larger growers seeing injury increasing and some reporting injury to be variable by block. These differences are shown in figure 11.

Figure 11.



Organic Management: Visual exploration of how mostly organic and mostly conventional operations regarding how injury increased/decreased if a grower is "mostly organic" (>75% organic acreage) or "mostly conventional" (>75% conventional acreage). These comparisons are shown in figure 12.

Figure 12.

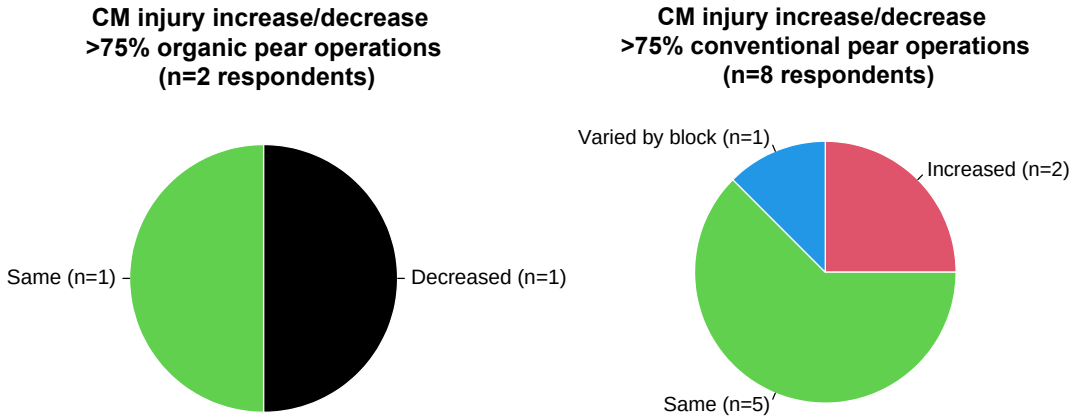


Pear Growers' response:

Small vs. Large Operations: There were no differences in whether CM injury increased, decreased, or remained the same on small vs large operations (p= 0.5727).

Organic Management: Visual exploration of how mostly organic and mostly conventional operations regarding how injury increased/decreased if a grower is "mostly organic" or "mostly conventional" (*note small sample sizes). These comparisons are shown in figure 13.

Figure 13.



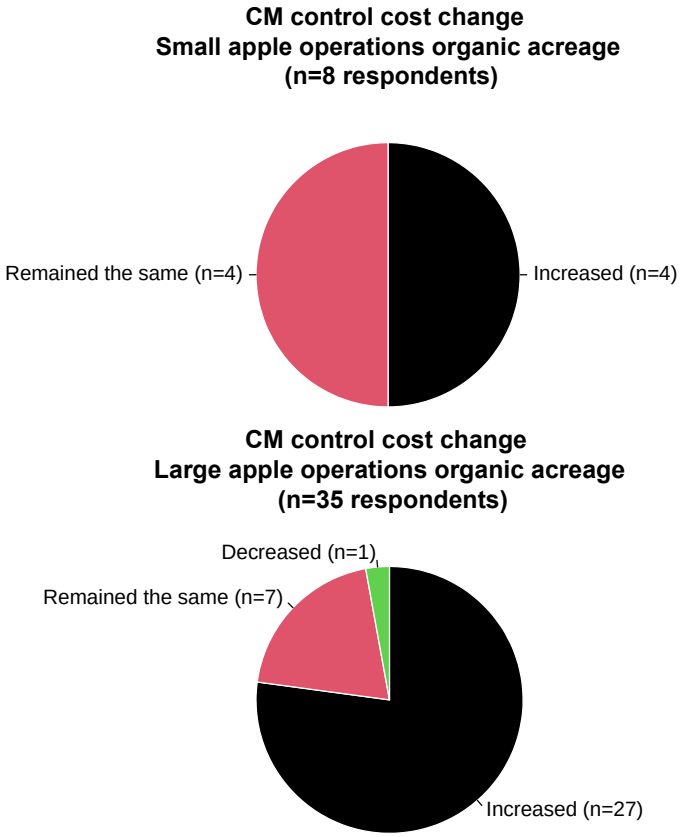
Question 8 Summary:
While apple growers reported quite variable and different results in CM injury changes between small and large operations, pear growers found no differences between large and small operations. In terms of difference in organic and conventional, only conventional growers of both apples and pears reported increases in CM damage, but again, note small sample sizes for mostly organic operations.

Survey Question 9 "Over the past 3 years, how did CM control costs change in your orchard?"
Answers were given for 3 different managements (conventional, organic, transitional). By breaking out the data in this way, the sample sizes are very small (especially for the number of small operations). Small and large operation comparisons were made within each management using chi-square analysis.

Apple Growers' response:

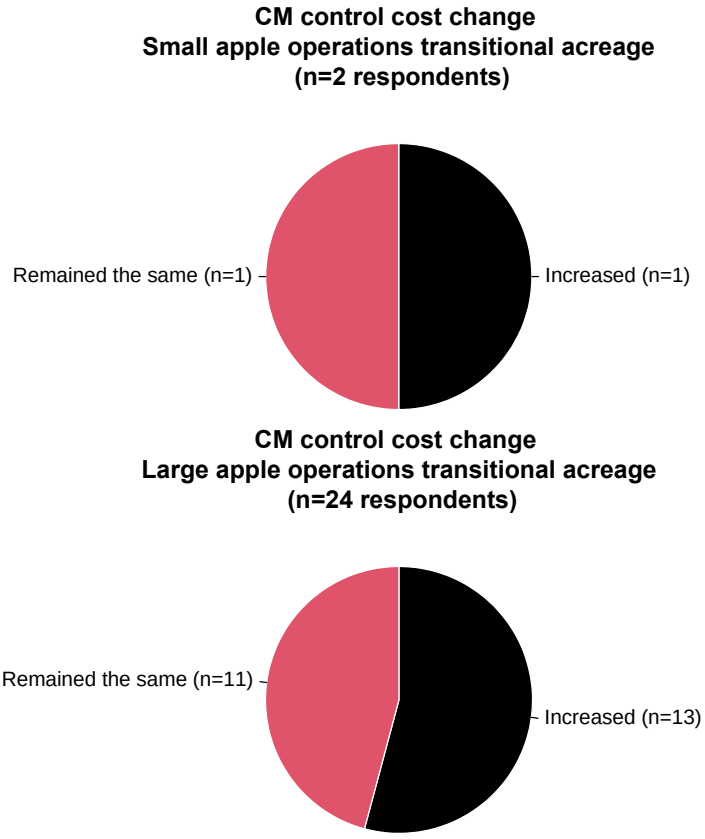
Small vs. Large Operations on organic acres: There was a difference between CM control cost changes on organic acreage, with a higher percentage of large operations reporting increased costs (p= 0.001). These differences are shown in figure 14.

Figure 14.



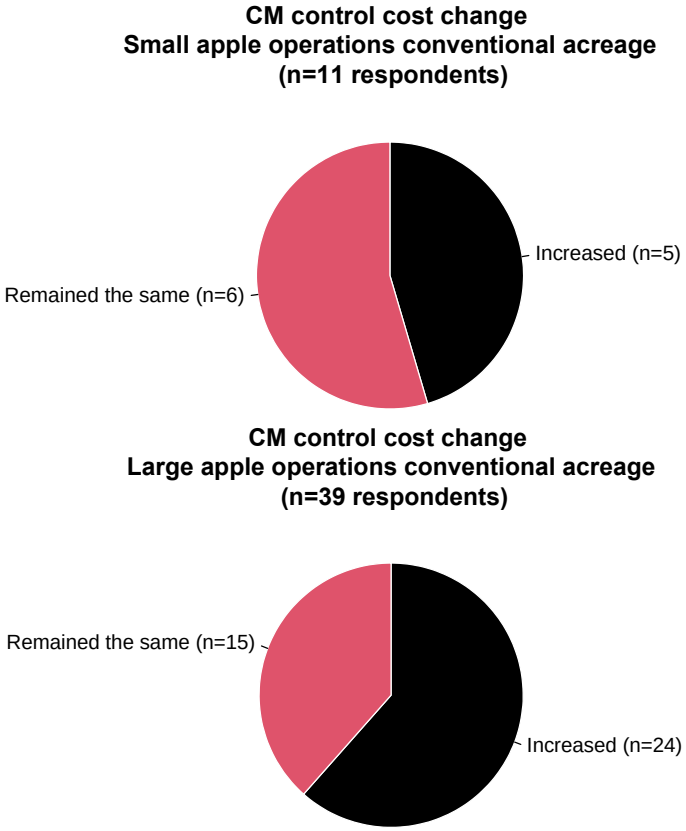
Small vs. Large Operations on transitional acres: There was a difference between CM control cost changes on transitional acreage, with a higher percentage of large operations reporting increased costs (p= 0.0075) (*note low sample size). These comparisons are shown in figure 15.

Figure 15.



Small vs. Large Operations on conventional acres: There was a difference between CM control cost changes on conventional acreage, with a higher percentage of large operations reporting increased costs (p= 0.0005). These differences are shown in figure 16.

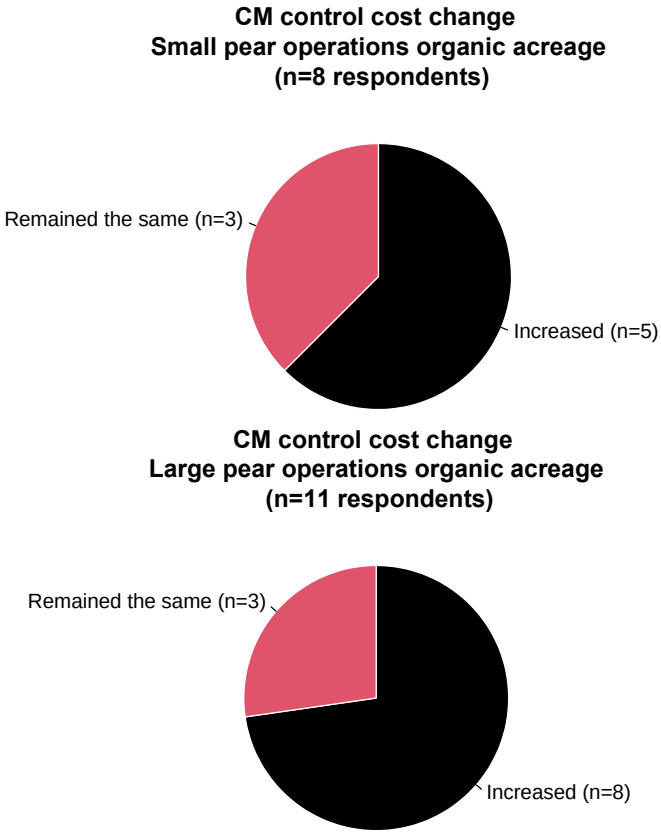
Figure 16.



Pear Growers' response:

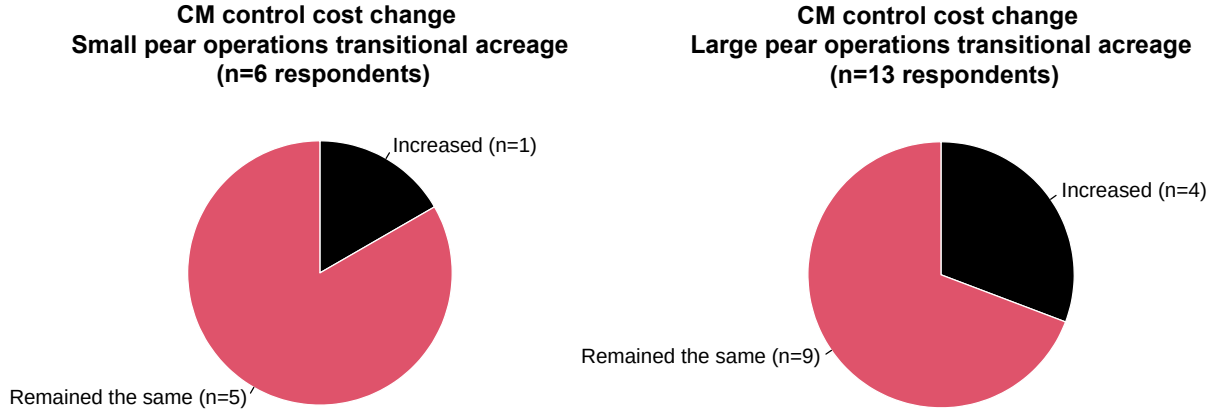
Small vs. Large Operations on organic acres: There was no difference between CM control cost changes on organic acreage (p= 0.6197). These comparisons are shown in figure 17.

Figure 17.



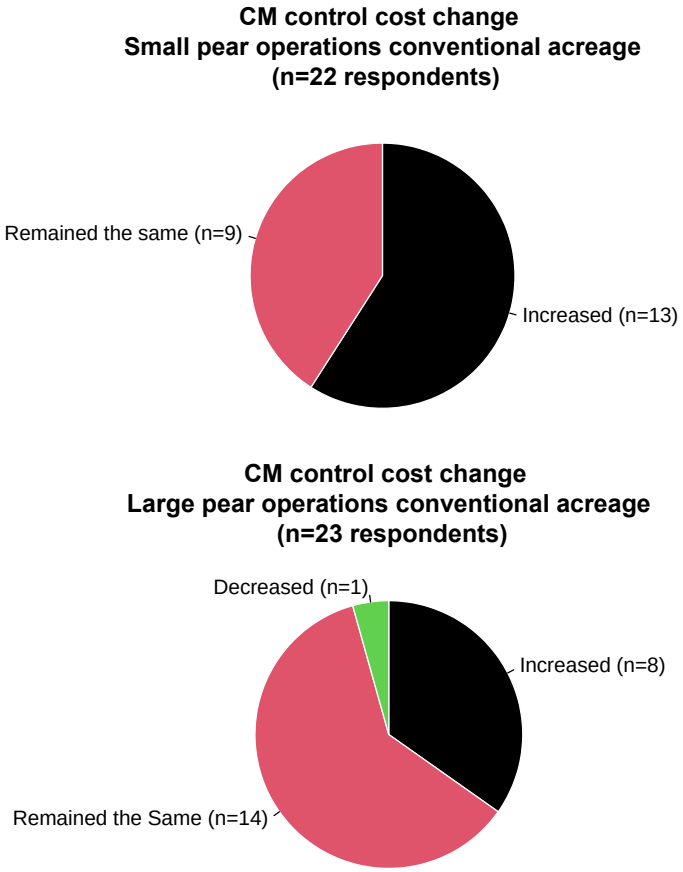
Small vs. Large Operations on transitional acres: There was no difference between CM control cost changes on transitional acreage (p= 0.09495). These comparisons are shown in figure 18.

Figure 18.



Small vs. Large Operations on conventional acres: There was no difference between CM control cost changes on conventional acreage (p= 0.2849). This comparison in shown in figure 19.

Figure 19.

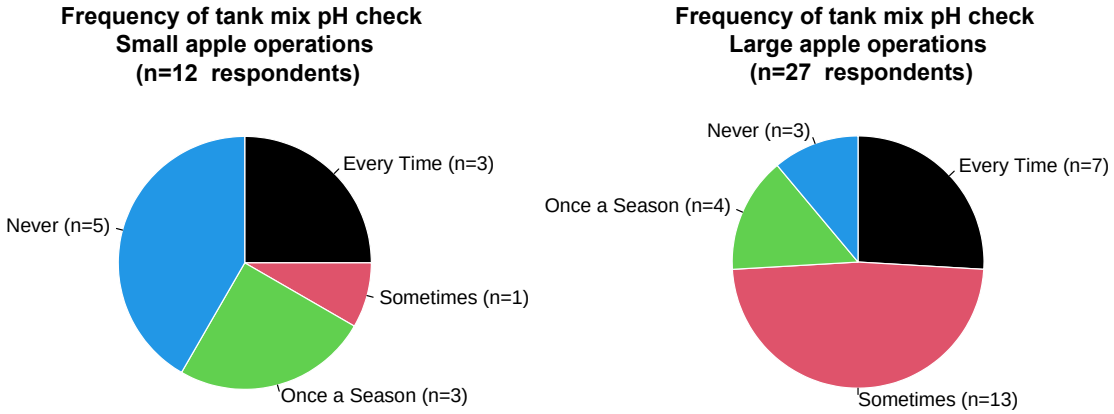


Question 9 Summary:
Interestingly, across all managements, large apple operations reported significantly increased costs associated with CM control. Pear operations did not experience this same difference.

Survey Question 35: "Most sprays, especially biologicals, are affected by the pH of the water used in the tank. How frequently do you check the pH level of the tank mix?" For the small vs large operations comparison, we used a chi-square test, and for the organic management, much like in Q7 and Q8, sample sizes were very small and differences are only visualized.

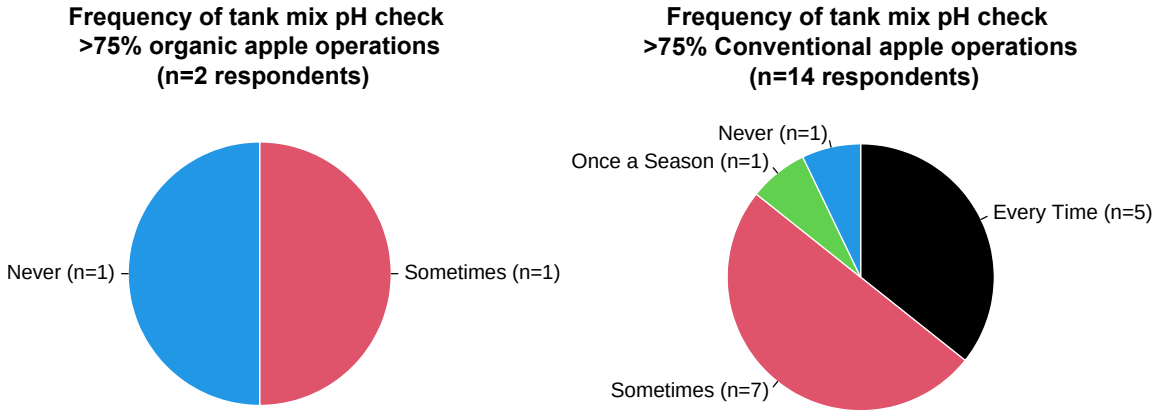
Apple Growers' response:
Small vs. Large Operations: There was a difference (p= 0.0025) in the frequency of tank pH checks between large and small growers. A majority of small operations checked the pH "Never", and the majority of large operations checking the tank pH "Sometimes". These differences are shown in figure 20.

Figure 20.



Organic Management: Visual exploration of how frequently "mostly organic" and "mostly conventional "operations check the tank pH. (*note small sample size). These comparisons are shown in figure 21.

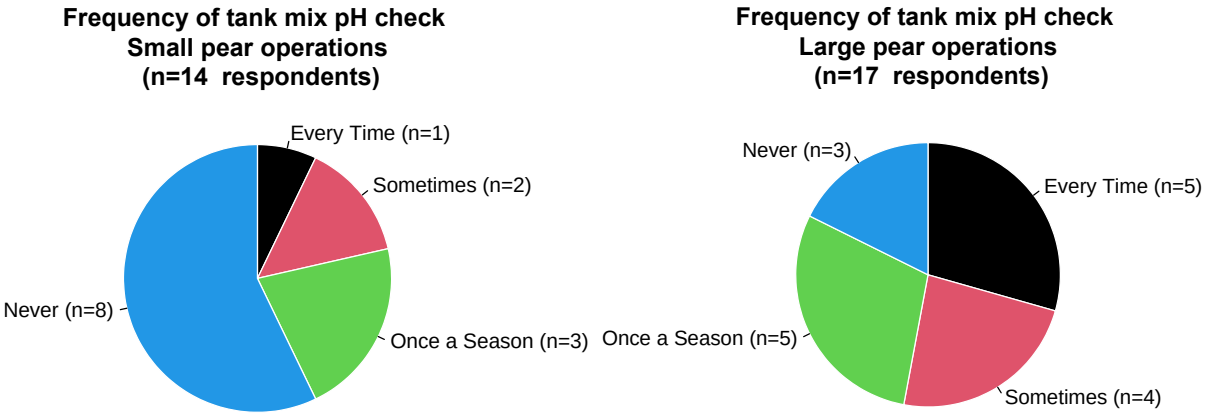
Figure 21.



Pear Growers' response:

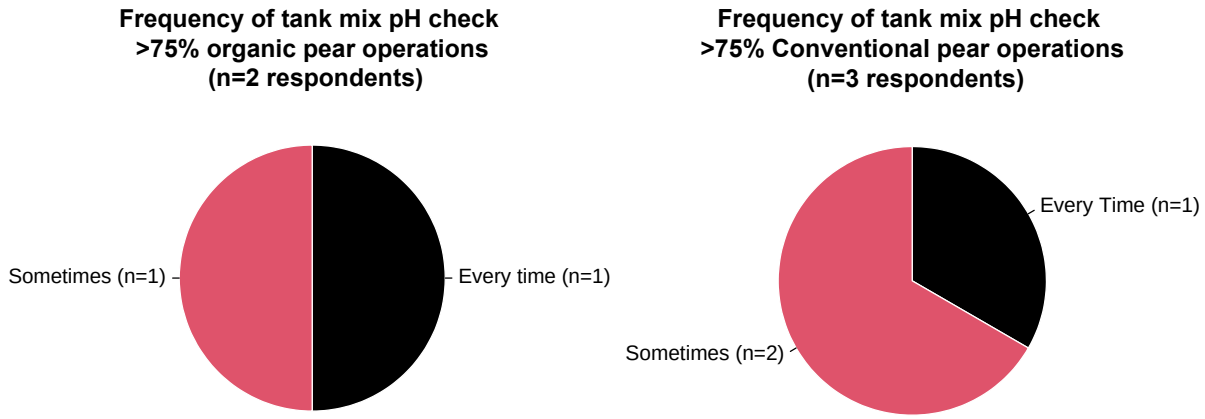
Large vs. Small operations: There was no difference found between small and large operations regarding the frequency of tank pH checks (p= 0.1609). This comparison is shown in figure 22.

Figure 22.



Organic Management: Visual exploration of how frequently "mostly organic" and "mostly conventional" operations check the tank pH. (*note small sample sizes). This comparison is shown in figure 23.

Figure 23.



Q35 Summary- It appears that across apples and pears of all sizes, about 3/4 of respondents could be checking the pH more regularly

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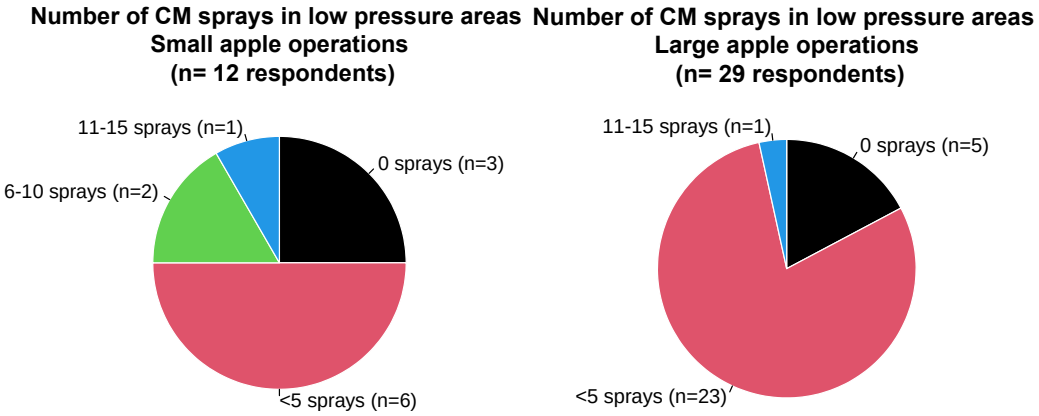
Survey Question 36 "How many codling moth sprays did you apply in low pressure areas in 2020?" We analyzed the small vs large operations with a chi-square test, and then visually explored the organic management differences.

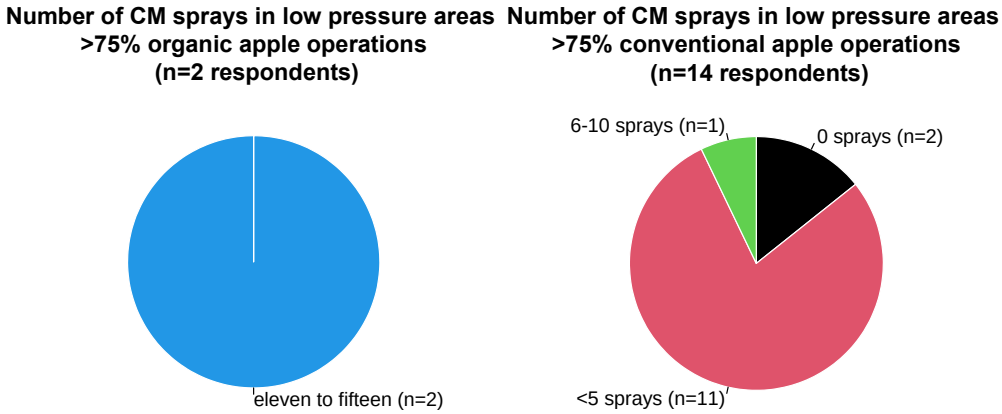
Apple Growers' response:
Small vs. Large Operations: There was a difference in the number of CM sprays in low pressure areas between small and large operations (p= 0.01649), with a higher percentage of large operations sprayed for CM <5 times, and a larger percentage of small operations spraying 6-10 and 11-15 times. These differences are shown in figure 24.

Figure 24.



Organic Management: Visual exploration of the number of CM sprays that "mostly organic" and "mostly conventional" operations used (note small sample size). This comparison is shown in figure 25.

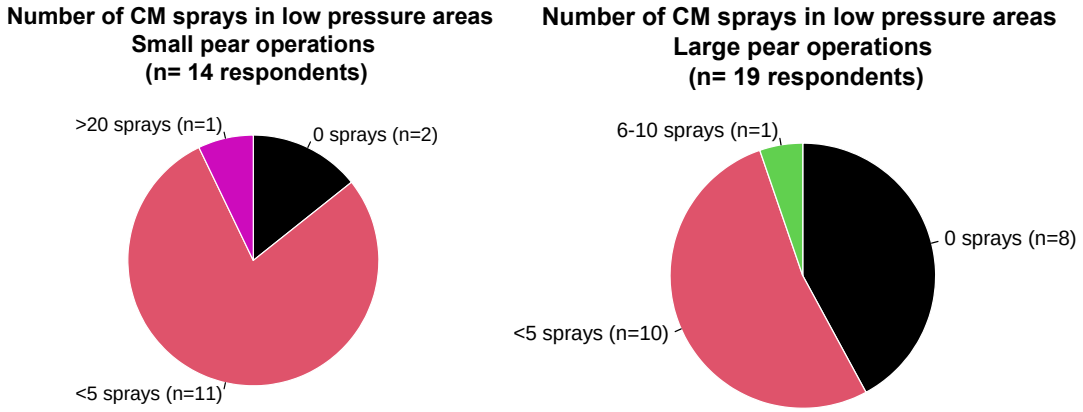
Figure 25.



Pear Growers' response:

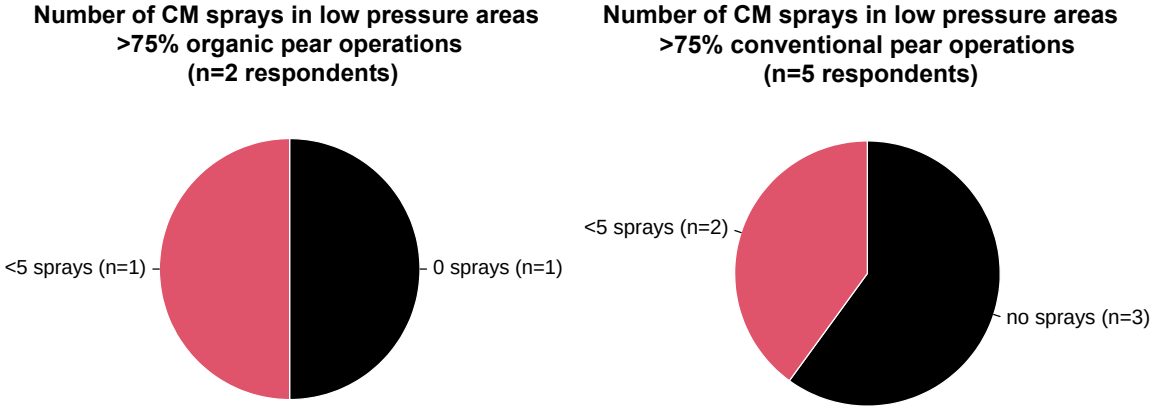
Small vs. Large Operations: There was not a significant difference in the number of CM sprays in low pressure areas between small and large operations (p= 0.08246). This comparison is shown in figure 26.

Figure 26.



Organic Management: Visual exploration of the number of CM sprays that "mostly organic" and "mostly conventional" operations used (again, note small sample sizes). This comparison is shown in figure 27.

Figure 27.

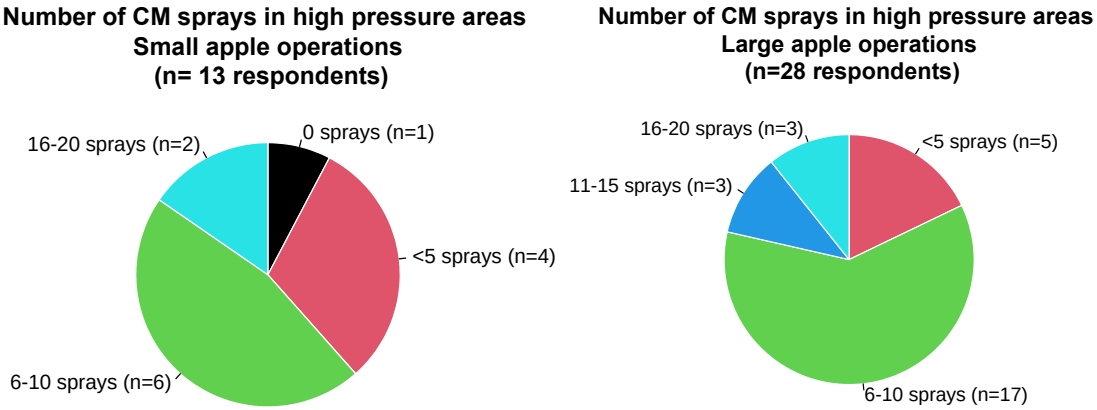


Q36 Summary: while there is some variability in terms of the number of CM sprays in low pressure areas, the majority of apple and pear operations are spraying <5 times, with small percentages spraying more.

Survey Question 37: "How many codling moth sprays did you apply in high pressure areas in 2020?" We analyzed the small vs large operations with a chi-square test, and the visually explored the organic management differences, due to very small sample sizes.

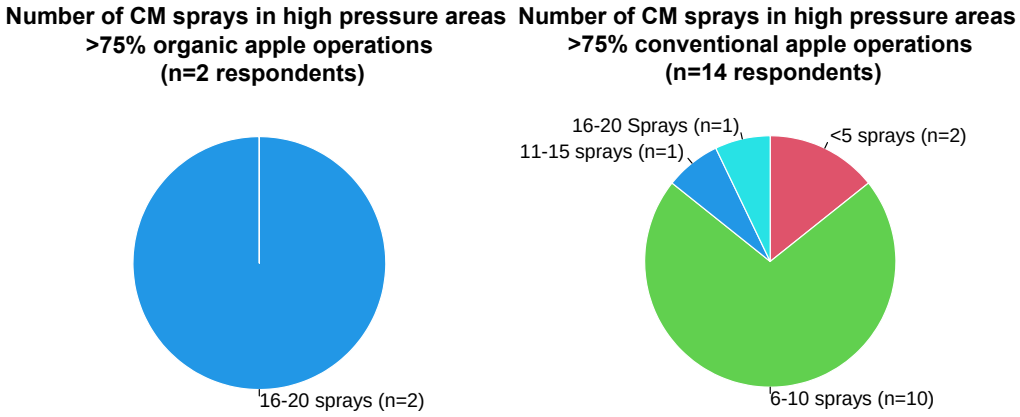
Apple Growers' response:
Small vs. Large Operations: There was a significant difference in the number of CM sprays in high pressure areas between small and large operations (p= 0.02699), with large farms spraying more. This difference is shown in figure 28.

Figure 28.



Organic Management: Visual exploration of the number of CM sprays that "mostly organic" and "mostly conventional" operations used (again, note small sample sizes). This comparison is shown in figure 29.

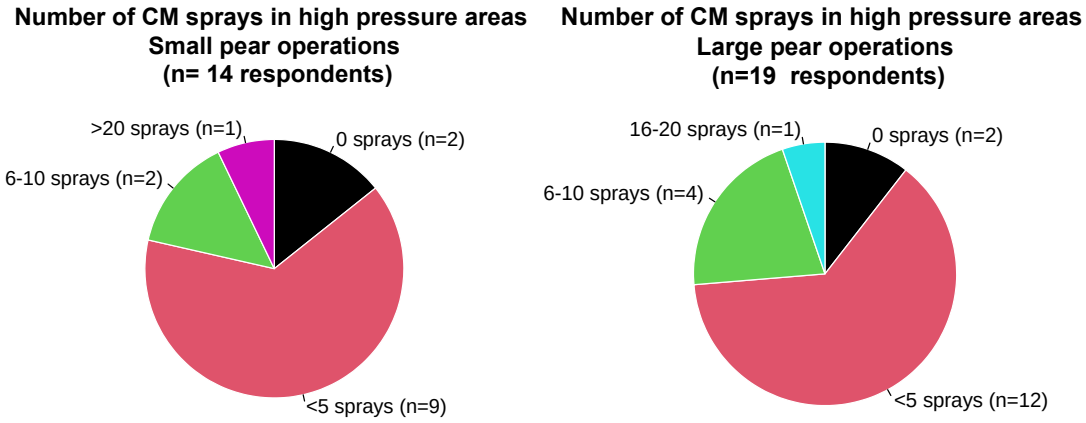
Figure 29.



Pear Growers' response:

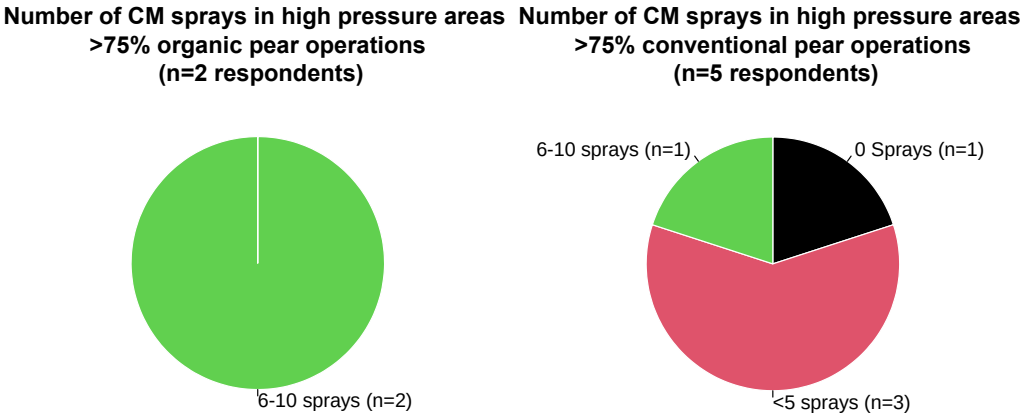
Small vs. Large Operations: There was no difference in the number of CM sprays in high pressure areas between small and large operations (p= 0.4603). This comparison is shown in figure 30.

Figure 30.



Organic Management: Visual exploration of the number of CM sprays that "mostly organic" and "mostly conventional" pear operations used (again, note small sample sizes). This comparison is shown in figure 31.

Figure 31.



Q37 Summary: In general, larger apple operations appear to be spraying their high pressure areas more times. Additionally, higher percentages of "mostly organic" operations (both apples and pears report spraying more times (although again… note small sample sizes).

Overall Report Summary:

Despite these survey data being relatively messy and the samples sizes being quite small, there are a few very interesting takeaways:

- Apple operations are experiencing consistent, unacceptable codling moth damage in a way that pear operations did not report.
- As apple operations grow a higher percentage of their acreage in organic, their threshold for CM damage goes up
- Central Leader (older trees) dominate as the most problematic tree structure across apples and pears
- Across organic, transitional, and conventional acreage, large apple operations reported significantly increased costs associated with CM control, relative to smaller operations.
- Most folks should be checking their tank pH more regularly
- Larger apple operations look to be spraying their high pressure areas more often than small operations.

The survey was created and distributed by the Codling Moth Task Force Committee appointed and supported by the Washington Tree Fruit Research Commission in 2020. The committee was comprised of growers, university researchers, and industry leaders. Data were compiled by Chris Adams. Analysis was done by Matt Jones (Cascade Agroecology, LLC) and Tobin Northfield (WSU-TFREC).