STUDENT RESEARCH REPORT – REEU PROGRAM 2022

Effects of Waterspout Pruning on Pest Insect Pear Psylla and Disease Risk Assessment

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Abstract

Pear psylla (*Cacopsylla pyricola)* is an invasive pest insect found throughout the United States that primarily affects European pear trees. The damage caused by pear psylla is due to the sticky honeydew left behind after feeding. Honeydew-related damage promotes diseases like sooty mold and causes russeting, reducing the aesthetics and sale price of the fruit. Additionally, toxins in pear psylla saliva injected during feeding can cause psylla shock, resulting in tree wilt. At present, we lack established cultural controls for managing pear psylla infestations. To amend this, we hypothesized that watersprout removal is an effective means of reducing psylla populations that is economically viable. To test our hypothesis, we measured pear psylla populations in fourteen blocks of trees from two orchards in Massachusetts. Each block contained four trees, randomized to have either one fourth, one third, three fourths or no watersprouts removed. Post pruning, sticky cards were installed to monitor adult population levels, while visual inspection of spurs and sprouts were conducted to record egg, nymph and adult numbers. Lastly, we collected the number of pruning man-hours also noting tree size. Overall, we found instances where pruning reduces pear psylla populations at all stages of development, but could not replicate these findings across time or between sampling sites. Although inconclusive, our data provides some incentive to compliment chemical controls with cultural controls, therefore reducing the environmental impact of commercial pear production.

Introduction

Pear psylla (*Cacopsylla pyri*), a pest insect of the order hemiptera that targets European pear trees, is one of the major causes of pear fruit damage in North America (Civolani & Perveen, 2012). As part of their life cycle, pear psylla mate for the duration of the summer and lay multiple broods of eggs (Tougeron et al., 2021). Therefore, generations of pear psylla come in 'waves' throughout the summer (Tougeron et al., 2021). After hatching, nymphs undergo five instar (developmental) stages, in which they crawl along the soft vegetation of pear trees to feed (Tougeron et al., 2021). Adults then develop into their flying form and are ready to reproduce (Tougeron et al., 2021). Overall, it takes around thirty days for one batch of eggs to fully develop into adulthood (Tougeron et al., 2021). During the colder months, pear psylla morph into a winter form which is darker and slightly larger than the summer form (Tougeron et al., 2021).

After morphing, pear psylla overwinter under the bark of trees for protection (Tougeron et al., 2021).

A study done by Horton and Landolt (2007) found that mating pear psylla males are attracted to females feeding and congregating on the tree's soft vertical shoots. When pear psylla feed on these shoots, they leave behind sticky honeydew residue, which causes damage to the leaves and fruits and can attract other pests like insects and sooty mold (Civolani & Perveen, 2012). In severe cases, toxins in the pear psylla saliva can cause psylla shock, which can eventually result in tree wilt and then death (Civolani & Perveen, 2012). Even in a scenario where feeding does not lead to tree wilt, it can still cause economic damage to fruit growers by creating russeting on the pear fruits (Civolani & Perveen, 2012), making the fruit less appealing and, therefore, less marketable (Weibel et al., 2007). Due to socioeconomic pressures, growers must maintain pristine, 'extra fancy' (perfect market grade) fruit conditions so that it may be purchased in the wholesale market (Weibel et al., 2007). Hence, even the cosmetic damages caused by pear psylla feeding can cause fruit to be turned away and wasted, substantially reducing a grower's income (Weibel et al., 2007).

To deal with pests that threaten farm economies, many commercial agricultural systems rely on 'calendar' spray cycles, meaning that farmers spray routinely; often on a weekly or monthly schedule (Afun, 1991). Although the impact of pesticides on human and beneficial insect health depends on the specific compound, concentration, and amount sprayed, chemical pesticides have known detrimental effects on a farm's overall ecology (Werf et al., 1999). Integrated Pest Management (IPM) advocates for the reduction of spraying down to the specific needs of farms, or even blocks within a farm (Dent, 1995). This strategy is based on maintaining pests population levels below an economic injury level, or the point at which pest damage becomes harmful to a farm's income (Dent, 1995). To do this, IPM uses multiple strategies, including cultural controls, a form of management based on manipulating plant cultivation to reduce pest pressure (Benbrook et al., 2000). Our study implemented the removal of pear tree soft vegetation, named watersprouts (Walser, 1994), as a way to reduce pear psylla populations (Benbrook et al., 2000).

Yet, novel management practices can have unseen side effects and cause more problems than they solve if done without care. In our study, pruning may increase the risk of pathogenic infections, such as fireblight; a vicious bacterial disease that affects fruit production trees and infects through wounds and naturally-occurring tree openings (Thomson, 1985). An active fireblight infection can kill trees within a single growing season and quickly spread from tree to tree via dead, infected debri which releases spores under the orchard canopy (Thomson, 2000). Overall, fireblight poses an even greater risk of economic damage to a fruit grower than pear psylla damage, which is mostly cosmetic. The injuries that invariably occur during pruning can act as a pathway for fireblight (Thomson, 1985), so it is possible that fireblight occurrence could increase with pruning practices.

As with any management practice, cost benefit assessment must be taken (Benbrook et al., 200). Pruning trees outdoors, often on tall ladders, can take multiple hours/days to complete, depending on the size of the orchard (Walser, 1994). Therefore, the cost of paying for laborers who are willing and skilled enough to complete the task can greatly affect farm finances. Many forms of pest management are often too expensive or timely for farmers, so care must be taken to make the practice affordable enough for growers if they are expected to use it (Benbrook et al., 2000). To this end, our study also assessed the time/cost needed to prune trees with workers.

Altogether, I hypothesized that watersprout removal is an effective means of reducing psylla populations that is economically viable. To test our hypothesis, we measured pear psylla populations in fourteen blocks of trees from two orchards in Massachusetts. Then we collected the number of pruning man-hours also noting tree size. Overall, we found instances where pruning reduces pear psylla populations at all stages of development, but could not replicate these findings across time or between sampling sites.

Materials and Methods

Data collection ran from mid-May until late August and started in Belchertown MA at the University of Massachusetts Amherst Cold Spring Orchard (CSO), followed by Bashista's Orchards (BA) in Southampton MA. Bosc and Bartlett varieties of European pear trees were pruned and sampled.

To assess the removal of watersprouts as viable means to control pear psylla populations one of four treatments including a control were assigned to each tree. Watersprouts were defined as soft wood/young shoots growing vertically off of branches. At CSO, the study was conducted on four rows of pear trees, with each row containing fourteen trees. Trees at CSO were Bosc and Bartlett varieties. Each row was split into two blocks, making eight trees total. Each block contained four trees with treatment and three 'buffer' trees placed at the beginning and end of each block to reduce the migration of adult pear psylla between treatments (Fig. 1). Treatment types were assigned in a randomized order. At Bashista's there were four rows of treatment trees, one with seven trees, one with ten trees and two with twelve trees. Trees at Bashista's were Bosc, Bartlett, Clapp Favorite, and D'anjou varieties. These were split into six blocks containing four treatment trees and at least one buffer tree on each side (Fig. 1).

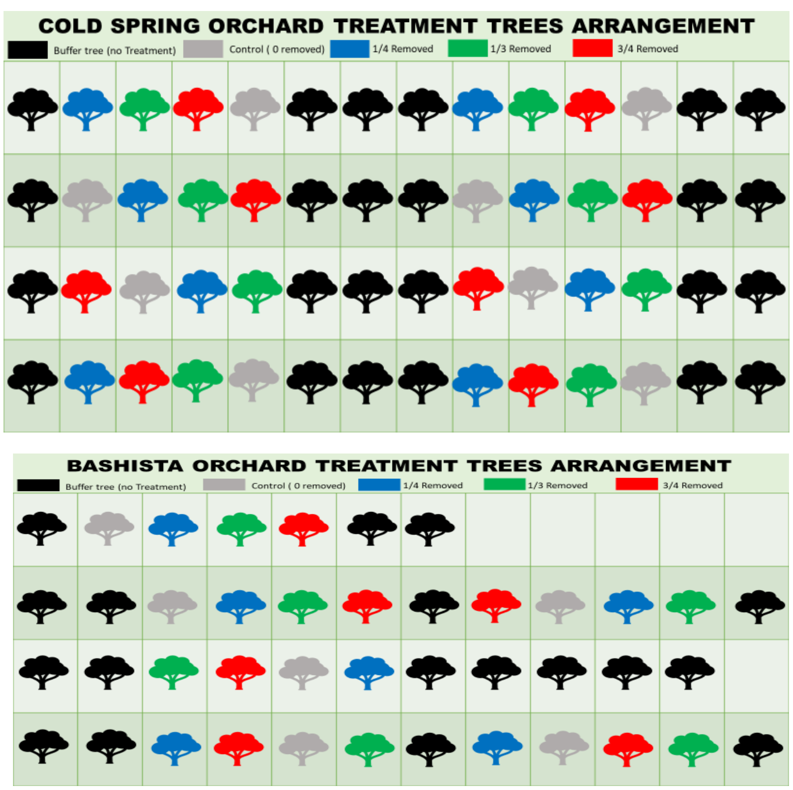


Figure 1. Detailed Map of Treatment Blocks for pear tree pruning at Cold Spring Orchard and Bashista's Orchard. Colors show treatment categories of watersprouts removed- control, one fourth, one third, and three fourths.

The tree treatments were one fourth, one third, three fourths, and no watersprouts removed (control) (Fig. 1). The buffer zone consisted of trees that were not pruned, and these were not surveyed for pear psylla or associated ailments. Treatments were assigned in a random order.

Watersprout removal treatments involved counting the total number of large branches (defined as a large tree limb attached to the main trunk) for each tree and multiplying them by the fraction of the assigned treatment, then rounding to the nearest whole number (e.g. a tree with 13 branches and ¼ treatment had 3 branches stripped of all watersprouts). Branches were then marked, selecting branches that were evenly distributed throughout the tree, and then stripped of all watersprouts. Watersprout removal took place in late May and early June. Attention was made to only prune in weather below 80 F and below 70% humidity on a sunny day, not adjacent to any major rain event to prevent the spread of fireblight.

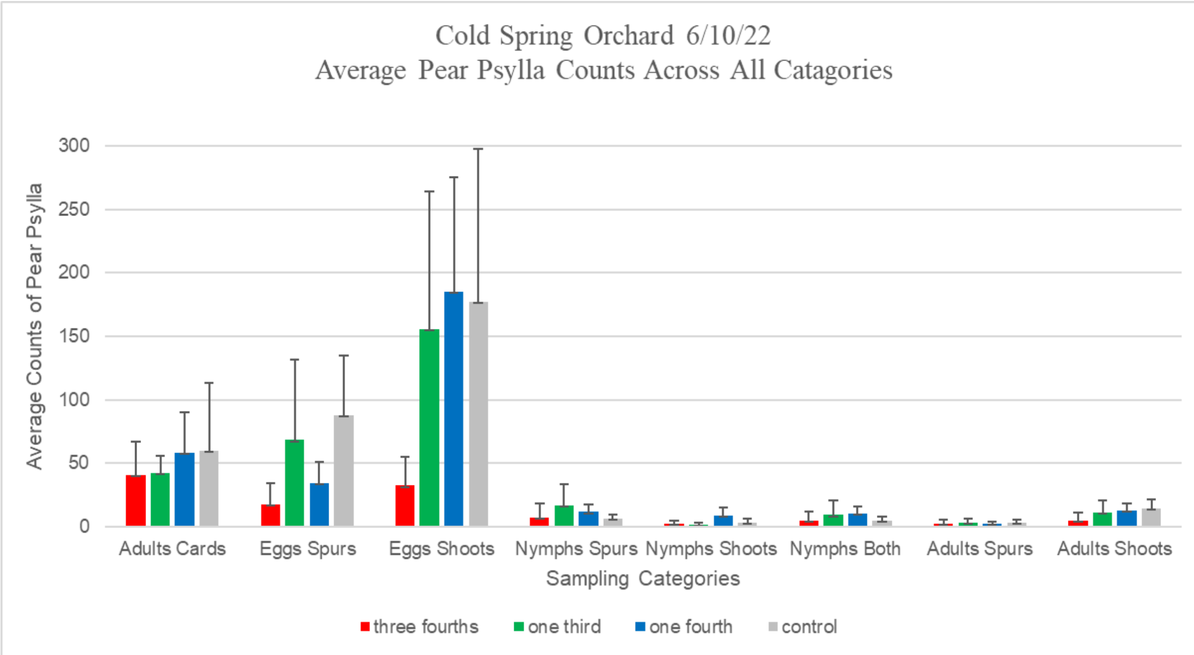
To assess the viability of pruning considering labor costs, additional data was collected; namely the number of workers pruning, the number of hours it took to prune during each session, and the relative size of the tree.

Immediately after pruning was completed, a single, clear, unbaited sticky trap (30cm x 30cm) was hung at head height from each treatment tree in order to monitor adult pear psylla. Starting on June 10th for CSO and June 24th for BA, sticky cards were inspected in the field to count adult pear psylla numbers. During the same visits, five shoots and five spurs from each treatment tree were inspected to monitor pear psylla egg, nymph, and adult numbers. This survey was repeated every two weeks, alternating between the two data collection sites, for a total of four sampling dates at each orchard. Including the control trees, we surveyed a total of 52 trees across all blocks of both orchards.

For data analyses, raw psylla numbers were square root transformed to reduce data dispersion. Means and standard deviation of transformed and raw data were also calculated. Significant differences between treatment types were assessed for each sampling category using analyses of variance (ANOVA). Average time spent pruning was calculated and multiplied by the Massachusetts State minimum wage, to assess minimal cost of labor involved in tree treatment.

Results

Across all categories and treatments, we found larger numbers of pear psylla at CSO, with a population maximum of 389 and a mean of 33 (4.4 after normalization). At BA, the population maxima was 143 with a mean of 13 (2.5 after normalization) All data, except for the first Bashista's Orchard sampling date, showed greater numbers of pear psylla eggs compared to nymphs and adults (Figs. 2 & 3). Further, adults on shoots and spurs consistently showed the smallest mean populations (Figs. 2 & 3).



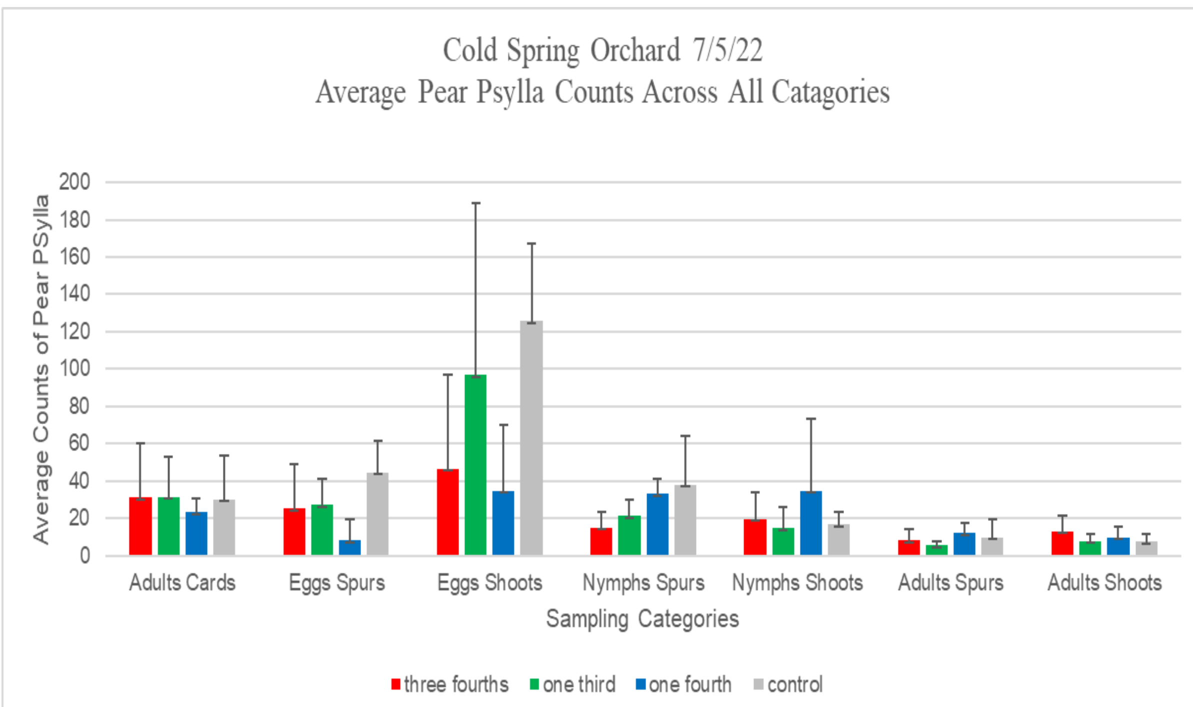
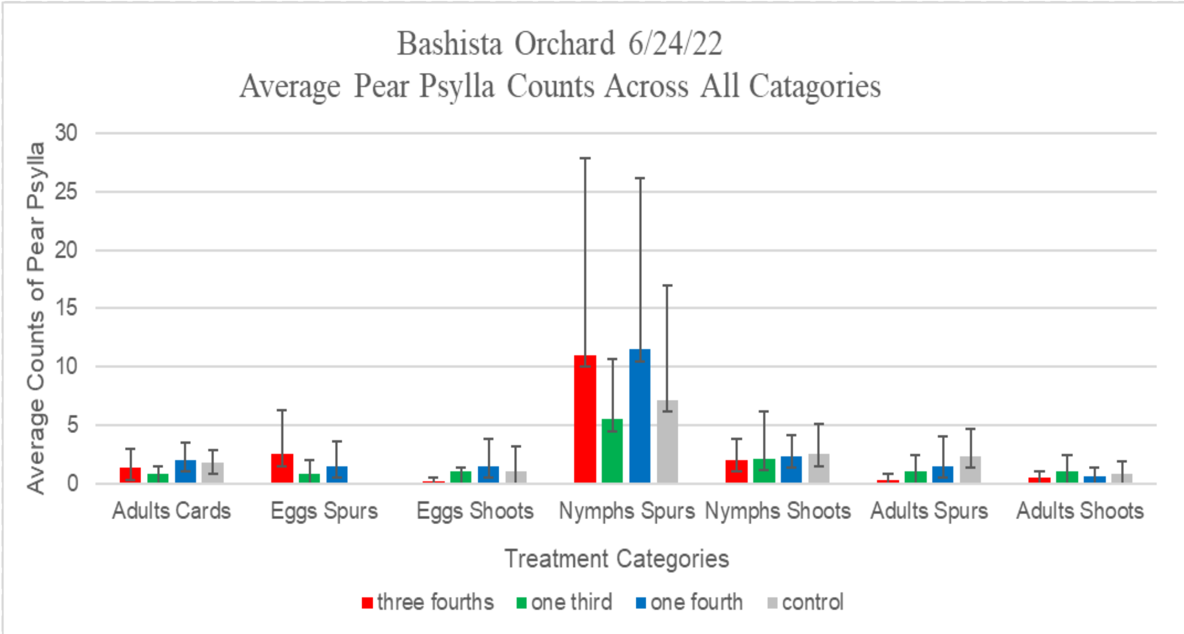


Figure 2. Mean pear psylla population counts from two sampling dates at the University of Massachusetts Amherst Cold Spring Orchard. Visually showing data trends of the raw population data.



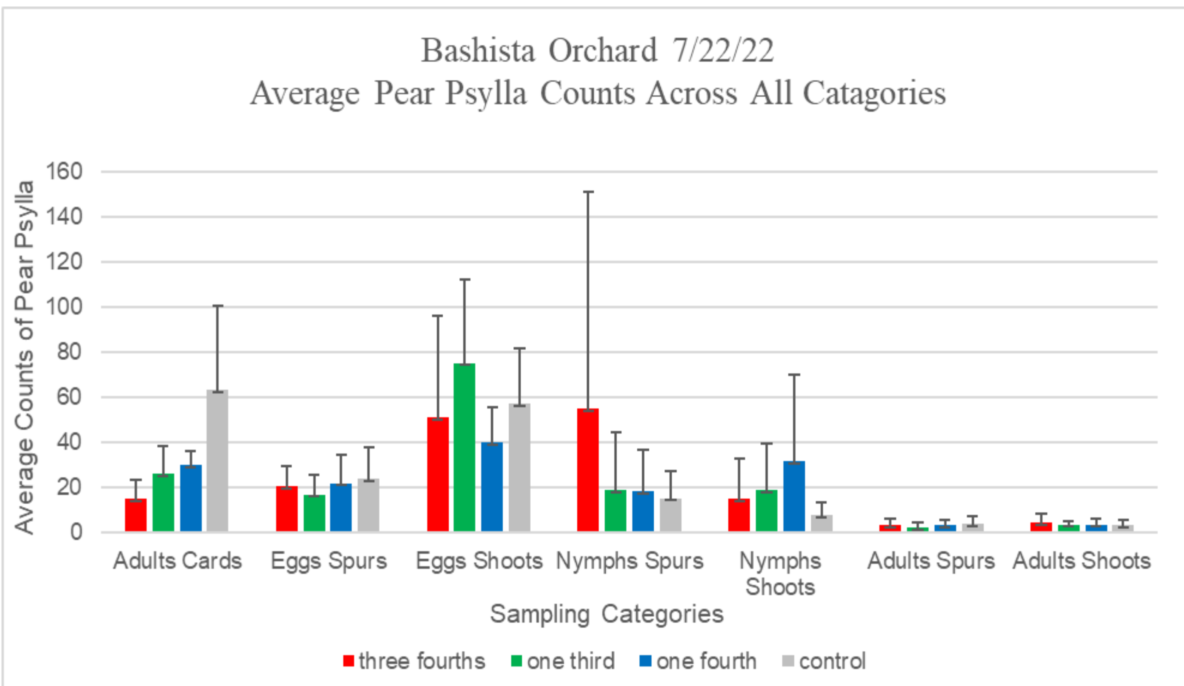


Figure 3. Mean pear psylla population counts from two sampling dates at Bashista's Orchard, showing trends in pear psylla population size.

Cold Spring Orchard results

No significant differences between treatments were found in the category 'Adults on Cards' for either sampling dates at Cold Spring Orchard (Table 1). Significant differences between treatments were not found for the category Eggs on Spurs for the first sampling date (Table 1). For the second sampling at Cold Spring Orchard, differences in treatment showed ($F_{3,15}$= 3.99, p=0.028), within the data there was a significant difference between the categories Control and One Fourth showing (p=0.003) (Fig. 4)

Table 1. Summary of test results for analyses of variance tests comparing the differences in pear psylla population for all data categories between treatment types. Statistical significance is highlighted in red, bolded text. Interactions are broken down between data collection dates at the two orchards.

P Values from ANOVA Tests Run Comparing Overall Differences Between Treatment Types for All Sampling Categories and Locations Across All Dates

	Cold Spring Orchard Date 1	Cold Spring Orchard Date 2	Bashista Orchard Date 1	Bashista Orchard Date 2
Adults on Cards	0.696	0.366	0.466	0.009
Eggs on Spurs	0.078	0.028	0.277	0.704
Eggs on Shoots	0.039	0.084	0.321	0.292
Nymphs on Spurs	0.028	0.057	0.927	0.357
Nymphs on Shoots	0.025	0.482	0.892	0.556
Adults on Spur	0.921	0.498	0.227	0.781
Adults on Shoots	0.078	0.499	0.923	0.974

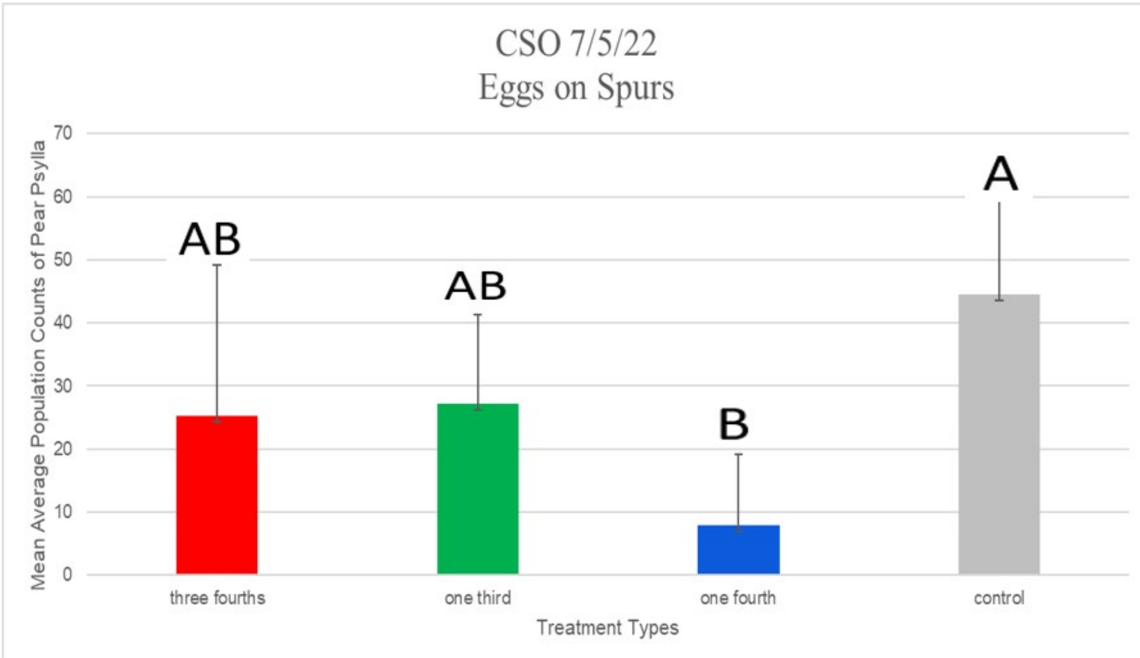


Figure 4. Average number of Pear Psylla Eggs surveyed from spurs of pear trees at Cold Spring Orchard on 7/5/22

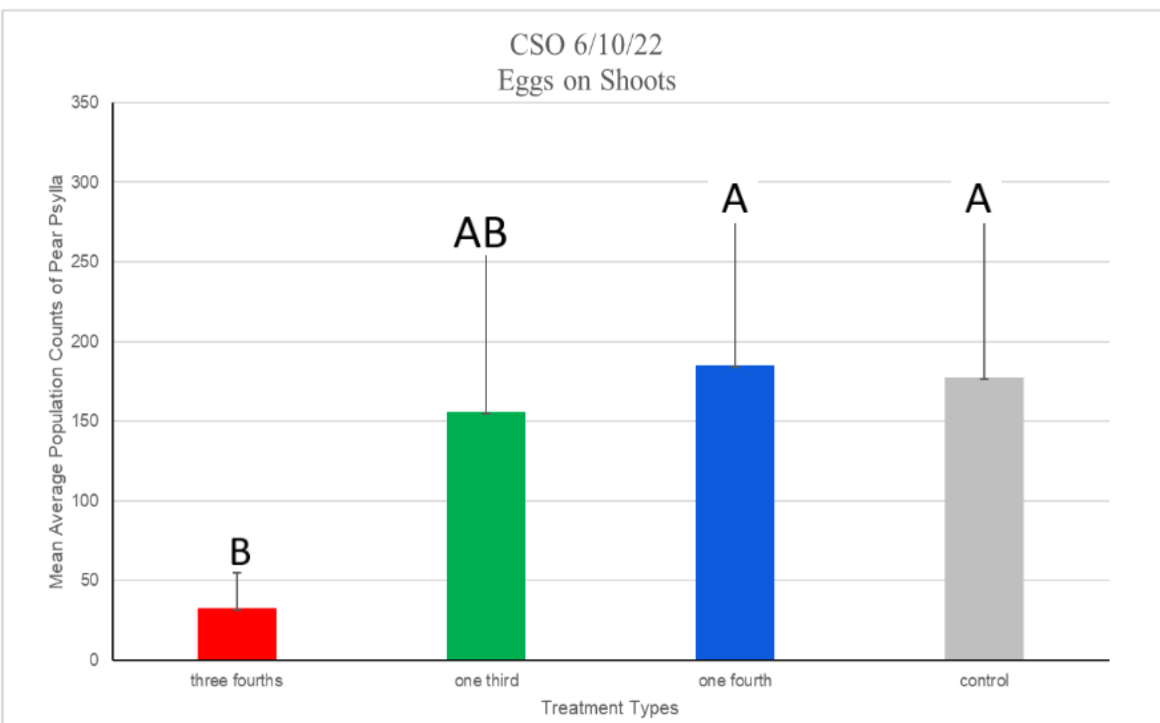


Figure 5. Average number Pear Psylla Eggs surveyed from shoots of pear trees at Cold Spring Orchard on 6/10/22

Significant differences between treatments were found in the category Eggs on shoots during the first Cold Spring Orchard Sampling date. (ANOVA $F_{3,15} = 3.58$, $P = 0.039$).

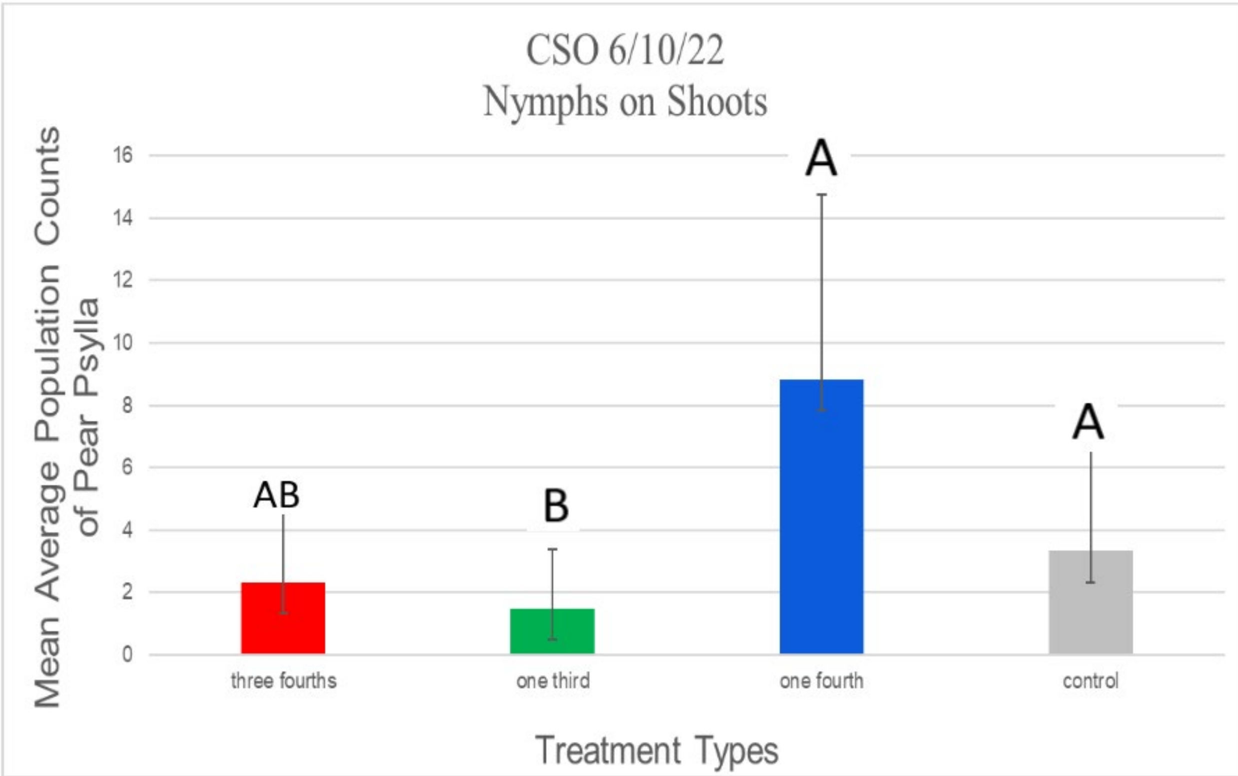


Figure 6. Average number Pear Psylla Nymphs surveyed from spurs of pear trees at Cold Spring Orchard on 6/10/22.

Within the data, it was shown that there was a significant difference between the categories, Control and One Fourth, compared with Three fourths.(P=0.014) and (P=0.007) respectively. At the second sampling date no significance was found (Table 1).

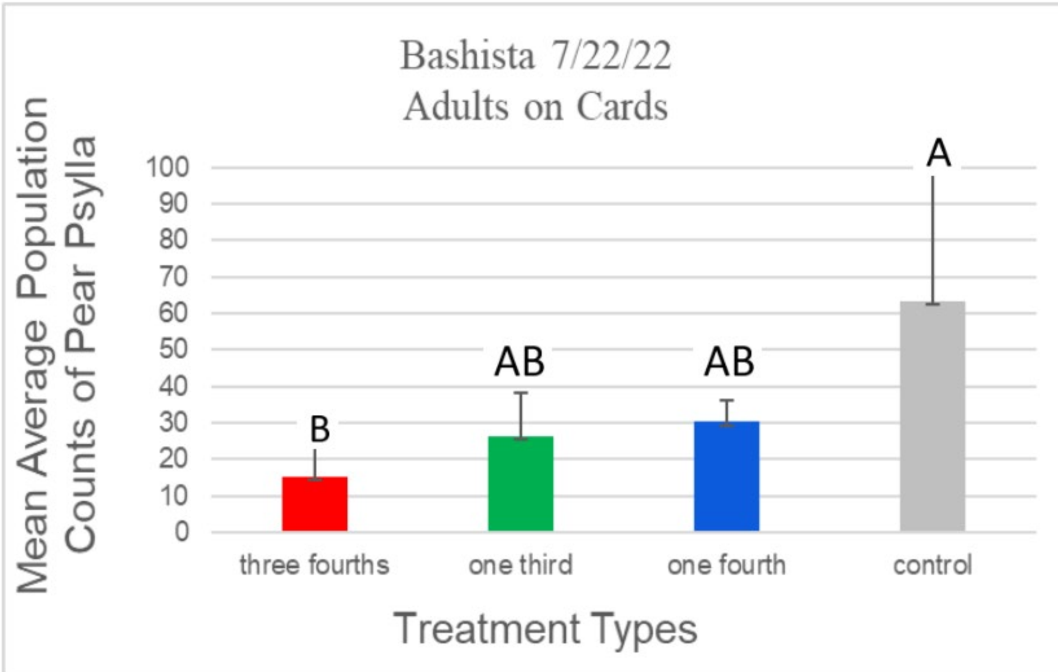


Figure 7. Average number Pear Psylla Nymphs surveyed from shoots of pear trees at Cold Spring Orchard on 6/10/22

Significant differences between treatments were found in the category Nymphs on Spurs in the first Cold Spring sampling date ($F_{3,15}$=3.99, P=0.028). Within this data, there was a significant difference between the categories One third removed, and Control, showing (P=0.013). At the second sampling date no significance was found (Table 1).

During the first Cold Spring sampling date, significant differences were found in the category Nymphs on shoots ($F_{3,15}$=4.13, P=0.025). Within this data there were differences between the categories, Control/One Fourth, versus Three fourths, showing (P=0.013) and (P=0.004) respectively (Fig. 7). During the second sampling date, no significant differences were found (Table 1).

For both categories Adults on Spurs and Adults on Shoots, no significant differences in population were found at Cold Spring Orchard for either sampling date (Table 1).

Bashista's Orchards Results

At Bashista's, the only category to show significant differences between treatment types was Adults found on sticky cards during the second sampling date. Analysis of this data showed that ($F_{3,15}$= 5.47, P=0.009). Within this data, there was a significant difference between all three categories-One fourth, One third, and Three fourths, versus the Control, showing (P=0.027), (P=0.013), and (P=0.002) respectively (Fig. 8). During the first sampling date, no significant differences were found on Adults on sticky cards (Table 1).

In all other categories- Eggs on spurs, Eggs on shoots, Nymphs on spurs, Nymphs on shoots, Adults on spur, and Adults on shoots, there were no significant differences found in both the first and second sampling date (Table 1).

Labor Costs

We found that for three workers, the average time to prune one medium standard tree of its watersprouts is 9 minutes. The median number of trees per row in this study was 12, so to complete one row of pruning on standard trees it would take 1.8 hours. Minimum wage in Massachusetts is $14.25, therefore, the minimum cost of pruning one row of trees (rounded to two hours) would be $85.50, for three workers.

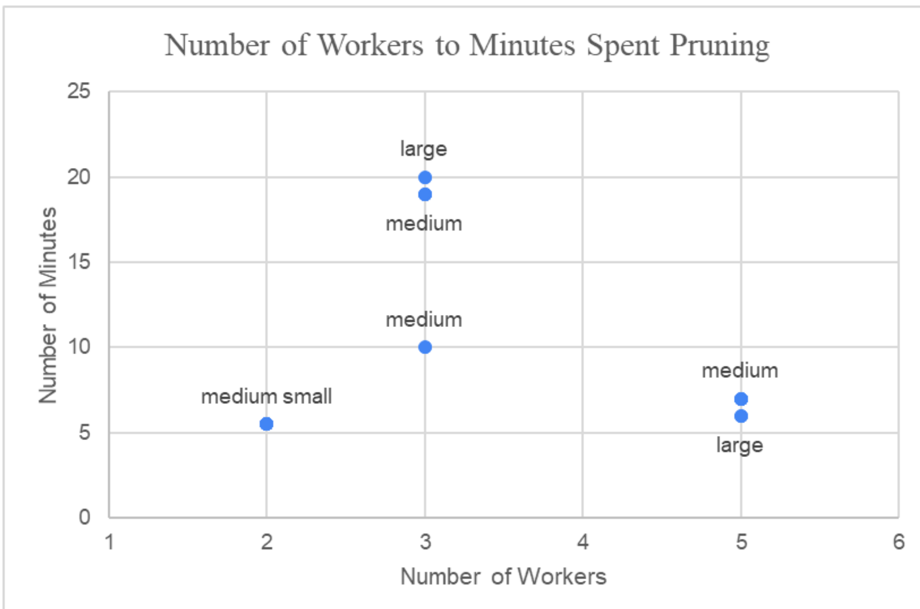


Figure 7 Number of minutes and workers it takes to prune pear trees relative to their size.

Discussion

I found a larger number of pear psylla at CSO than Bashista's, which may be due to historic populations and previous management practices. While speaking with farmers, it was discovered that CSO had problems with pear psylla in the block where we collected data, which at the time was sprayed with chemical pesticides to fight the infestation. Meanwhile, at Bashista's, there had been a traditionally lower number of pear psylla, with the primary form of management in the form of tree pruning and IPM scouting.

Cold Spring Orchard. One row of pruned trees at CSO was excluded from data collection and analyses because the trees never developed fruit. Fruitlets and their surrounding vegetation are a major habitat for pear psylla that provides them with food and shelter, so a lack of fruit would likely cause lower population levels and skew our data. During the first sampling date at CSO, there was a greater number of psylla eggs on the shoots of control and one-fourth pruned trees than trees with three fourths of the watersprouts removed (Table 1). This same exact trend was also seen for nymphs on spurs, as well as nymphs on shoots (Table 1). All of this data seems to suggest that watersprout removal decreases pear psylla populations when the majority of the watersprouts are removed. Unfortunately, these trends were not replicated during the second sampling date.

It could be possible that the effects of pruning waned off as the summer progressed as trees regrew vegetation. In future experiments, it may be worthwhile to consider pruning the trees twice per summer. Other possible reasons for the mixed results could be that pear psylla become more opportunistic as population pressure increases. In other words, psylla may choose less optimal habitats within trees with most of their watersprouts removed, but may not necessarily die or migrate to other trees. Migration to other trees may also involve heightened resource competition with the established psylla populations, but we ignore the saturation range for the population capacity of pear trees.

Bashista's Orchards. At Bashista's, we found that the only category to show a significant difference in psylla levels between treatment types was Adults found on sticky cards during the second sampling date, where control trees had a higher population of adults than trees with three fourths of their watersprouts removed. There were no other effects of pruning in the data collected at BA, suggesting that, in general, pruning had no effect on pear psylla population levels. Additionally, the pruning effects reported at CSO were not replicated at Bashista's.

Lower population levels at Bashista's could explain the lack of pruning effects. On the one hand, the population levels may have been too low to be affected by the treatment. On the other hand, the probability of finding pear psylla in general may have been low enough to introduce sampling bias due to a lack of random distribution of psylla across the tree. In other words, because there are so few pear psylla, sampling of five shoots and spurs across the tree may not be sufficient to produce a truly random (and therefore representative) sample. However, this explanation fails to address the fact that we also did not see an effect of pruning for adult population levels surveyed via the sticky traps.

Labor Costs. My study found that the average row of trees would take $85.50 to prune for two hours and three workers assuming that farmworkers get paid minimum wage. This would not be a substantial cost for a small-scale Massachusetts Orchard, but other factors to consider include the time spent both pruning and finding willing workers. While pruning and pesticide use may have comparable financial costs, pruning would take much longer than pesticide spraying, due to the skilled hand labor nature of the job (Walser, 1994). Many farmers have difficulty finding laborers and need to spend extra effort to find good quality workers. Although these are not financial costs, the time and effort cost of these actions should be taken into consideration when recommending this management practice.

Limitations

As part of their life cycle, pear psylla spawn new generations in 'waves' throughout the summer (Tougeron et al., 2021). Fluctuations in pear psylla population due to brood hatches may have therefore confounded our analyses, since we collected data every other week, failing to take into account the thirty days it takes for new eggs to develop into adults (Kapatos & Stratopoulou 1996). In future replications of the experiment, data collections should be done within the same week or every month, the latter of which would allow for the populations of psylla across their development to 'reset'.

Notably, our study was conducted under drought conditions for the majority of the summer, which may have had an effect on pear psylla breeding capabilities. As seen in a study by McMullen, R., and Jong, C. (1972), high temperatures can reduce fecundity of female pear psylla. Future studies with varying weather conditions could compare replicates with 2022 data to gain some insights on how changes in pear psylla reproduction affects the effectiveness of pruning as a management strategy.

Watersprouts begin growing when the tree breaks dormancy and continues throughout the growing season (Walser, 1994). If watersprouts continuously grow, they may need multiple prunings throughout the season to have an effect on pear psylla populations. Additionally, with 2022 being a drought growing season, watersprout growth may have been stunted/slowed affecting the results of the study by reducing pear psylla habitat within the trees. The same could be said for fruit on the trees, which is targeted by pear psylla for feeding. This may have changed the result of the study; therefore, it should be repeated in additional years with varying weather conditions.

Adult pear psylla may fly between trees and 'cross contaminate', not giving us a clear breakdown of how different treatments affect population levels between trees. In the future, replications, buffer trees should be implemented between each treatment tree, rather than just between each group of treatment trees to reduce the number of adult pear psylla crossing from tree to tree. In general, adult pear psylla are the hardest to sample, as they can quickly fly away when disturbed, which may explain why they had the lowest counts in the data. Developing better methods for sampling population levels may be needed to get accurate results in the future.

We also consider possible sampling errors. In general, pear psylla live in a clustered pattern, with adults congregating on vertical shoots for mating where females also lay their eggs (Stratopoulou and Kapatos, 1992). In our study, we observed that eggs tend to be concentrated on young vertical shoots; specifically on the still developing leaves near the tip that have not yet acquired a dark green color. On these leaves, we sometimes recorded hundreds of eggs, while eggs were seldom found in other, more developed vertical shoots with fully grown leaves. As it is rather subjective to decide whether a shoot is developed enough to likely have pear psylla, the study should be tweaked to look for pear psylla populations more specifically.

When choosing data collection sites, we did not account for management practices, which resulted in having data from two orchards with different spraying and pruning practices. In general, data from more locations with similar management practices may allow us to obtain more accurate results.

Lastly, we hired untrained undergrads to help prune the trees and during the first CSO sampling date, which may have been conducive to operator effects. Pruning is a skill that is built on experience and subjective discernment, deciding whether or not a shoot should be removed or not (Walser, 1994). While parameters of what shoots to remove were explained to student volunteers, the possibility of error (such as accidentally removing from the wrong branch, or under pruning on selected branches) still exists. Moreover, this may have skewed the labor cost results, as more experienced workers may be faster at completing the task.

Conclusions

Collectively, I found partial evidence (mostly form CSO) to support the hypothesis that removing watersprouts from pear trees reduces pear psylla populations. I also found that pruning is relatively inexpensive and it does not increase the risk of fireblight infection. It would be extremely beneficial to have a larger scope for collected data, geographically and throughout different weather conditions, so that future studies could be generalized to the greater New England area.

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